CLINICAL SIGNIFICANCE OF THE ANATOMICAL VARIATIONS OF THE BRACHIAL PLEXUS

Dissertation Submitted For

M.S.ANATOMY

BRANCH -V DEGREE EXAMINATION

TAMIL NADU DR.M.G.R. MEDICAL UNIVERSITY

CHENNAI

SEPTUMBER 2006.

CONTENTS

The brachial plexus is one of the most complex structure of the peripheral nervous system that supplies the sensory and motor innervation of the upper limb except trapezius muscle.

The brachial plexus originates from the ventral rami of fourth to eighth cervical roots and first thoracic root providing motor and sensory innervation. The brachial plexus is formed by the ventral rami of C5, C6, C7, C8 and T1 roots behind the scalenus anterior. Between the scaleni anterior and medius in the lower part of posterior triangle, of the five roots the upper two unite to form the upper trunk, the lower two unite to form the lower trunk and the central root continues as the middle trunk. Each trunk divides into anterior and posterior divisions behind the clavicle to supply the flexor and extensor compartments respectively. At the outer border of the first rib, the upper two anterior divisions unite to form the lateral cord, the anterior division of the lower trunk runs as the medial cord, while all the posterior divisions unite to form the posterior cord. These three cords enter the axilla above the first part of the axillary artery, embrace its second part and gives off branches around its third part.

The main branches of the cords are;

1. Median nerve - formed by the fusion of a branch from medial cord and a branch from lateral cord (C5, 6, 7, 8, T1).

2. Ulnar nerve - from medial cord (C7, 8, T1).

3. Musculocutaneous nerve - from lateral cord (C5, 6, 7).

4. Radial nerve - from posterior cord (C5, 6, 7, 8, T1).

5. Axillary nerve - from posterior cord (C5, 6).

During the routine dissection of the upper limb, I noticed that there was a communication between the 4^{th}, 3^{rd} common palmar digital nerves in the hand which instigated me to study on this variation. During my search on the internet, I found lot of literatures regarding the anatomy as well as the variations of the brachial plexus. While discussing with surgeons, they stated that it is important to be aware of these variations before making an incision, as even the safest incision in the normal anatomy might result in injury of the nerve with variant anatomy, also in evaluation of an unexplained nerve palsy after trauma, surgical intervention of particular area, neurotization of neural injuries, arthroscopy and in reconstructive surgeries. Discussions with the oncologist revealed that these variations have to be kept in mind especially during radical axillary dissection where-ever sparing of the nerve is mandatory. The physicians told that these neural variations should be thought of, while managing recurrent compression neuropathies and unusual clinical symptoms and signs. These statements warranted a deeper study in to the realms of brachial plexus. Also the higher incidence of the brachial

plexopathies reflects its vulnerability to trauma and the tendency of disorders involving adjacent structures to affect secondarily. The anatomy of brachial plexus is still very difficult to understand due to the frequency of variations in the course, structure, relations and distribution. Also being inaccessible to palpation, the clinical evaluation of brachial plexus is very challenging and localization of the lesions is very difficult. Since most of the brachial plexus disorders do not involve the entire brachial plexus but, rather show a regional predilection, regional approach to the assessment of plexopathies is necessary. This is an important region where the anaesthesiologist, plastic surgeon, oncologist, radiologist land up with problems frequently due to variations and the mismanagement will result if they are not aware of anatomical variations.

For an anatomist, it is important to facilitate the knowledge of anatomical variations to other allied disciplines. Hence this study focused on the variations of brachial plexus and their impact and chose to disseminate requisite information.

THE BRACHIAL PLEXUS.

Numbers of studies have been on the brachial plexus since the 18th century.

Walsh (1877) described the pre and post fixed types of brachial plexus.

Cunningham (1877) found the fibers of T2 joining T1in twenty seven out of 37 cases.

Paterson (1896) noted the contribution of T2 to T1 in eleven out of 33 cases.

Harman (1900) showed T2→ T1 fibers in seven out of 12 specimens.

Harris (1904) stated that only in post fixed types, it might be expected that the T2 would join to 1st and contributed to plexus. In his report, the prefixed type noted in 21.5% of the instances and the post fixed in only one instance. He reported on the anatomical variations of brachial plexus in human in 1904.

Kerr (1918) dissected 175 plexus and found that

- C4, C5 contributed 62% of nerve fibers of brachial plexus.
- Fibers from C4-C7 formed the lateral cord in 3/175.
- The medial cord formed from C8, T1 in 94.58%.
- In 5 cases, the medial cord formed from C7.

Poynter (1920) noticed the relation of axillary artery with medial and lateral cords as it passed in between them.

Linell (1921) noted variations in the composition of fiber bundles and absence or communication between its branches.

Adachi (1928) stated that variations of the brachial plexus were often accompanied by abnormalities of upper limb vessels (fig 1).

Trotter (1930) found an anomalous relation of axillary artery with cords of brachial plexus due to its development from 9^{th} inter segmental artery passing inferior to the medial cord.

Miller (1934) named the brachial plexus as post fixed when T1, T2 largely contributed. He classified the brachial plexus into 3 types according to his observations.

Brash (1953) described the three trunks, cords and branches to the upper limb.

Fenart R (1958) described the morphogenesis of the brachial plexus and its relation to the formation of neck and arm.

Chuchkov KH (1963) reported on the branches of the supraclavicular part of the brachial plexus.

Presta M (1963) studied the primary cords of brachial plexus in fetuses and adults.

Arey (1966) based on the variations of brachial plexus, stated that the developmental difference or alteration of the brachial plexus once formed would persist postnatally.

Fischer L et al (1971) studied the anatomical variation of scaleni muscles and brachial plexus relationships.

Bisenkov NP, Popovich MI (1973) showed an individual variation in the relationship between the sympathetic trunk and the brachial plexus.

Still JM Jr, Kleinert HE (1973) noted an anomalous muscle and nerve entrapment in the wrist and hand.

Mansat M (1977) explained the surgical topographic anatomy of the brachial plexus.

Miranda DR (1977) identified the brachial plexus's perivascular space.

Vasickova Z (1977) described the neural anastomosis in the human forearm (tab I).

Zverina E, Stejskal L (1979) demonstrated the innervation of biceps brachii from C3, C4 and phrenic nerve which restored its function even in complete brachial plexus root avulsion.

Zagrebin AM, Ehuchkor VM (1980) submitted a data on the stages in the formation and arrangement of micro vessels in neural fascicles (tab II).

Hollinshed (1982) said that the medial cord represented only the continuation of anterior division of lower trunk containing C8, T1.

Urbanowicz Z (1982) presented a report on the internal structure of suprascapular nerve and the postnatal development and arrangement of thoracodorsal nerve in man.

Bonnel (1984) described the angular variation of roots in their intrarachidian and cervical portions in 100 brachial plexus and histological study in 21 brachial plexus for the fascicular organization for achieving good functional recovery.

Partridge BL et al (1987) confirmed the presence of incomplete septa within the brachial plexus or axillary sheath making the compartments. Therefore they did not support the need for multiple injections when performing an axillary block.

Atoji et al (1987) studied the brachial plexus in Japanese Serows and noted the classical C5 - T1 nerve contribution in 98.1% and T2 joined in 1.9% .The manner of union of ventral divisions and their divisions were classified into 4 types (tab III).

Lengele B, Dhem A (1989) showed multiple anomalies in 3 specimens of axilla.

- The medial fascicle was absent in 1 case, also the brachial artery took an aberrant course through the median loop.
- Also the distribution of middle trunk was variant showing the lateral fascicles.

Lee et al (1992) reported on variation in the ventral roots of 152 brachial plexus in 77 Korean cadavers and their findings (tab IV) showed that the average diameter of C6, C7 ventral rami was the greatest while that of C5 as the smallest (fig 2).

Urbanowicz (1994) made out 3 types of brachial plexus based on the findings in the roots bilaterally in 69 men (tabV) and in 1995 mentioned the accessory root coming from the middle trunk took part in its formation of the medial fascicle.

Ahmet uzun (1995) studied 130 brachial plexus in 65 cadavers (34males, 31females of 1-7 days age) according to the length, diameter, sex where the plexus was formed from C5-T1 in 90 specimens(69.23%); Part from the C4 in twenty out of 65 infants (30.77%) and he classified the variation into 3groups (fig 3).

Yan J et al (1998) re-evaluated the innervation of brachialis in 16 cadaveric arms;

- The radial nerve supplied it constantly in all the sixteen out of 16 and no median nerve supply.
- Brachialis (mostly) received a branch from musculocutaneous nerve and (partly) from radial nerve.
- A communication between these nerves in 3 cases.
- The nerve composing a branch from musculocutaneous nerve derived from anterior divisions of ventral rami of C5, C6 nerves.
- The nerve composing of a branch from radial nerve (ventral root of C6, C7) was present in the same bundle of that of musculocutaneous at C6 in 1 and 3 cases.

Budak F, Gonenc Z (1999) studied in 108 subjects about the Martin-Gruber anastomosis (tabVI).

Yan J et al (1999) clarified that the suprascapular nerve belonging to both anterior and posterior divisions of brachial plexus by fiber analysis method in 6 cadavers (tab VII).

Z.Asli Aktan et al (2001) studied the axillary and brachial parts of the brachial plexus in 48 upper limbs and found that

- The communication between the musculocutaneous and median nerves in five (3left, 2right) – 10.43%, but not bilaterally. It left the musculocutaneous nerve at about 0.95 +/- 0.42cm from the formation

of the latter. The point of entry into median nerve was at 10.25 +/- 2.32cm from the formation of median nerve. The mean length of it was 5.50 +/- 2.50cm.

- The suprascapular nerve formed from the union of C4,C5 directly (Fig 4) in one arm.
- A branch from median nerve to brachial artery was in 1 case (fig 5).
- The formation of radial nerve from the posterior divisions only of middle and inferior trunks (fig 6).
- The left phrenic nerve connected to the upper trunk by a branch.

Hansasuta et al (2001) advised that while doing neurotization of musculocutaneous with medial pectoral nerve, the planning for interpositional graft would be the ideal based on the results in 35 brachial plexus (tab VIII).

Vyshnepl'skii Alu, Guzhov DA (2001) noted the rare variations of the brachial plexus viz.,

- The formation of median nerve at the border between the middle and inferior 1/3rd of brachium.
- A variant musculocutaneous nerve origination from lateral fascicle of brachial plexus by several branches.

- A variant lateral antebrachial cutaneous nerve originating from lateral fascicle by 2 branches.

Akila K et al (2002) reported on the cutaneous innervation of the subacromial region by the lateral pectoral nerve in two out of 125 sides (1.6%).

Ongoiba N et al (2002) studied 23 brachial plexus (13females, 10males) for anomalies (tab IX).

Uysal II et al (2003) noted the variation in 107 out of 200 brachial plexus formation in spontaneously aborted fetuses and more frequently in females and on the right side (tab X).

Matejcik V (2003) found the variations from the point of origin to the termination in 110 plexus and noted plexiform but not the spinal roots (tab XI), (fig 7).

Fazan et al (2003) studied the brachial plexus in 27 cadavers (21males, 6females), two distinct colours (12whites, 15blacks), 56 upper limbs and found variations (fig 8).

Matejcik V (2005) studied the incidence of neural root variation in 100 brachial plexus and found the prefixed type in 24cases (48%); post fixed type in 1case; other variations in 14 cases (28%), bilateral in 4 cases, left side in 9 cases.

MEDIAN NERVE

It is the commonest nerve showing variations quiet frequently among all the branches of the brachial plexus and extensive studies are still going on.

Martin (1763) was the one who first described the communication of median with ulnar nerve and Gruber demonstrated that in 15.2% of the arms (fig 9).

Turner (1864) defined a connection at the arm level between the median nerve and musculocutaneous nerves.

Thanes (1892) showed an abnormal branching of the brachial artery into radial, ulnar and inter -osseous arteries with associated median nerve variation.

Vallois (1922) noted two communicating branches between the musculocutaneous and median nerves and the brachialis was innervated by the nerve fibers from the site of union of the distal communicating branch and the musculocutaneous nerve.

Hirasawa (1931) found the connection from the median nerve to the musculocutaneous nerve (Opposite direction, common being from musculocutaneous to median nerve).

Miller (1934) compared the communication of median and the musculocutaneous nerves in monkeys and apes. And the connection might represent the primitive nerve supply of the anterior arm muscles.

Ferner (1938) demonstrated a communication from median to the musculocutaneous nerves (opposite direction).

Benassy (1965) described about the transposition of the musculo cutaneous nerve upon the median nerve.

Lanz (1977) dissected 246 hands and found twenty nine variations in the course of the median nerve and classified these variations into four groups (tab XII) and emphasized the importance of approaching the median nerve from the ulnar side while opening the carpal canal.

Crutchfield et al (1980) pointed out the hereditary aspects of the median and ulnar nerve communication and found that 28% general population and 62% of family members of five propositi with this variant and is dominantly inherited.

Winkelman (1980) showed an aberrant sensory branch of the median nerve to third web space.

Grant (1980) demonstrated the various relationship between the median nerve and brachial artery (fig 10), the palmar communicating branch between the 3^{rd}, 4^{th} common digital nerves (fig 11).

Tillmann (1981) studied the position, course of the median nerve through the forearm and carpal tunnel in 111 adults, 3 children and 12 infants's upper limb specimens and found that.

- The deviations from the normal position in 10% of adults.
- The nerve did not run radially, but between the tendons of 3rd and 4th fingers of flexor digitorum superficialis through the carpal tunnel in 5%.
- The median nerve does not pass superficially but deep beneath the flexor tendons of the fingers either radially or in the middle of the carpal tunnel.

The same findings where observed in the infants also. This aspect helped during surgical procedures for opening the carpal tunnel.

Tsikaras et al (1983) observed in eighty year aged male cadaver that the right median nerve was formed by the union of two nerve trunks, one originating from the upper and other one from the middle trunks of the brachial plexus(C5,C6,C7) with subsequent absence of the lateral cord of brachial plexus. The place of junction laid at 52mm from the exit of C6, C7 nerves from the spinal cord. The musculocutaneous nerve arose from the median nerve after a 38mm course of the latter. He finally stated that despite

the absence of fibers from C8, T1neurotomes in the trunk of the median nerve, the distribution of its branches was normal.

Kitayama et al (1985) found an unusual high division of median nerve.

Watanabe et al (1985) showed the fusion of the musculocutaneous and median nerve in 2 specimens (fig 12).

Mumford (1987) studied the gross and inter-fascicular anatomy of the terminal part of thenar branch of the median nerve in 20 fresh frozen cadavers (tab XIII).

Amadio (1987) reported a case in which the radial half of a bifid median nerve passed through a separate compartment within the transverse carpal ligament where the nerve gave off sensory and motor branch to the thumb. These two branches subsequently rejoined distal to the transverse carpal ligament.

Dellan, Mackinon (1987) dissected 31 cadaveric upper limbs to study a variant musculofibrous arches causing median nerve compression at the forearm. They inferred that the median nerve was

- Crossed by two, one or no fibro-aponeurotic arches.
- Compressed by an accessory head of flexor digitorum longus, Gantzer's muscle – in 45% cadavers.
- No ligament of Struthers was found.

Le Minor (1990) reported on the variant origin of the median and the musculocutaneous nerve where the lateral fascicle of brachial plexus pierced the coracobrachialis, giving muscular braches to coracobrachilis, biceps brachii and then divided at the middle of arm into two terminal branches., the first one trifurcated giving two branches for the brachialis and the lateral antebrachial cutaneous nerve ,the second one corresponded to the lateral root of median nerve and depending on these ,the nerves were classified into 5 types(tab XIV) (fig 13).

Srivastava (1990) showed in 2 out of 134 upper limbs (1.5%), the persistent median artery splitting the median nerve into two roots in the forearm and the artery passed through the nerve.

Iwamoto et al (1990) worked on the fascicular arrangement of the communicating branch between the median nerve and musculocutaneous nerve in five cases. They observed

- The branch to coracobrachialis received fibers from C7 before leaving the brachial plexus in three cases, after leaving in one case.
- In one case, the communicating branch was observed from median nerve to musculocutaneous nerve, the fibers from C7 joined the median nerve via medial cord.

- The communicating branch between the median and the musculocutaneous nerve consisted of fibers from C5, C6 in all examined cases.

Lenen et al (1991) described the neurotization of the median nerve in the hand by radial nerve by dissecting 30 hands, as the diameter of radial branch approximated that of its palmar digital homolog, the anastomosis was made at the wrist or through the first and second inter-osseous spaces. This helped to obtain faster sensory re-innervation in the sensory disorder.

Ferrari, Gilbert (1991) described the connection between the median and ulnar nerves in 50 cadaveric palms in both sexes and that was found in 45 hands (tab XV) (fig 14)

- In forty three out of 45 palms, the communicating branch originated proximally from the ulnar nerve and proceeded distally to enter the third common digital nerve.
- In 2 palms, the branch left the median nerve to reach the fourth common digital nerve.

Urbanowicz (1992) carried out dissection bilaterally on bodies of 51 males and 52 females ranging from 1day to 87 years and demonstrated variations, asymmetry in the thickness of the lateral root of the median

nerve, number of fascicles, size of cross sectional area of fascicles and index of the fascicular area.

Urban (1992) made out a branch that ran separately from the main trunk of the median nerve in a 53 years old White man and appeared to be the common digital nerve to third and fourth fingers.

Leibovic et al (1992) revisited Martin – Gruber anastomosis and defined a new classification (tab XVI).

Nakashima (1992) classified the Martin – Gruber anastomosis by examining twenty three out of 108 cadaveric arms (tab XVII).

Naff et al (1993) undertook dissection in 21 cadavers where they found that the palmar cutaneous branch of median nerve originating as high as 11cm radially and proximal to the wrist crease.

Nebot et al (1994) correlated the presence of accessory fascicle of the pronator teres and entrapment of the median nerve in 60 upper limbs of which 8.3% showed an accessory fascicle.

Saundo et al (1994) demonstrated an anomalous median nerve with persistent median artery where the nerve formed a ring enclosing the median artery, gave off its third palmar digital branch in the forearm and had a high palmar cutaneous nerve origin and double thenar supply.

Sargen et al (1995) reported a variant formation of the median nerve at the level of brachial plexus where it was formed by the fusion of three branches, one from the medial cord and two from the lateral cord. The abnormal root coming from the lateral cord had a very close oblique course over axillary artery. They imparted this knowledge to surgeon as ***"the incidence of injury was high in radical neck dissection, axillary dissection and also this variant might reduce the blood supply of upper extremity due to compression".***

Williams PL et al (1995) clarified the classical description of the course and relation of the median nerve in the upper limb which was recorded in 82.8% of 1000 dissections.

Olave et al (1996) carried out the morphometric study of the muscular branches of the median nerve in 60 palmar regions from 30 cadavers of adult of both sexes aged between 23 and 77 years. They found that (tab XVIII)

- They arose from the lateral branch of the median nerve in 83.3% of the cases.
- The point of recurrence of the branch was localized topographically 34.6 +/-3.6mm from the distal wrist crease.
- In 50% of cases the muscular branch innervated the abductor pollicis brevis, opponens pollicis and superficial head of flexor pollicis

brevis. In 40%, it supplied only the abductor pollicis brevis and opponens pollicis. In 10%, the short muscular branch gave rise to independent branches in the palm supplying abductor pollicis brevis,Opponens pollicis and superficial head of Flexor pollicis brevis

Al – qattan (1996) showed the relation between the Gantzer's muscle and the median nerve, anterior inter-osseous nerve in 25 limbs where he noted that the Gantzer's muscle was always posterior to both median nerve and anterior interosseous nerve and the variations in this muscle may contribute for compression syndrome.

Nakatani et al (1997) encountered the superficial brachial artery descending ventral to the median nerve and divided into radial and ulnar arteries in the cubital fossa.

Taams (1997) assessed the incidence of Martin- Gruber anastomosis in 56 preserved South African cadavers and the connection was found in 13 cadavers (23%) and one was bilateral. There were no significant racial / sexual differences in the incidences.

Ihunwo et al (1997) demonstrated the distribution of median nerve to muscles of anterior compartment of arm and associated complete absence of musculocutaneous nerve (bilaterally).

Steinberg et al (1998) based on the dissection of 46 hands (15 females, 8 males) they observed various patterns of distribution of median nerve viz.,

- In 33 hands, the median nerve had normal distribution of its branches.
- In 13 hands, the nerve was trans-ligamentous where the recurrent branch pierced the carpal ligament 2 – 4mm proximal to the distal end of carpal tunnel.

Venieratos et al (1998) classified the communication between the musculocutaneous and median nerves in sixteen out of 79 cadavers (22 communications) (tab XIX) (fig 15).

Shu et al (1999) classified the Martin –Gruber anastomosis in 72 upper limbs.

Stancic et al (1999) studied the frequency of the superficial palmar communication (Berrettini branch) between the median and ulnar nerves in 100 fresh cadaveric palms and noted it in 81% and it was classified by Ferrari and Gilbert into four types (tab XX).

They reported that ***"In 28% of hands, this branch was proximal to the distal edge of transverse carpal ligament. Berrettini branch can be considered as a normal anatomical entity and which may be injuried iatrogenically in both one portal and two portal endoscopic surgeries"***

Bas et al (1999) performed dissection under microscopic magnification on 30 fresh cadavers to know the course and inter-connections of sensory nerves of digits and 67% of cadavers had the communication between the median and ulnar nerves in the palm (fig 16).

Sanes et al (2000) noted a communication between the median and the musculocutaneous nerves and stated that this significant variation in the nerve patterns might be as a result of altered signaling between mesenchymal cells and neuronal growth cones.

Prasada Rao (2000) observed 8 instances of the communication between the musculocutaneous and median nerves in twenty four upper limbs from 12 preserved Zimbabwean cadavers of both sexes. The communication was either before or after piercing the coracobrachialis. In 2 instances, the musculocutaneous nerve was not piercing the coracobrachialis. In 2 instances the communicating branch arose after the origin of muscular branch to biceps brachii.

Haviarova Z et al (2001) noted an atypical course of brachial artery passing through fork of the median nerve, in front of it along the whole of its course (fig 17).

Choi et al (2002) demonstrated the variation in the connections between the musculocutaneous and median nerves in 138 cadaveric arms. These

variations were seen in 64 cadavers (46.4%), 9 bilaterally and 55 unilaterally (26 right, 29 left arms).They classified these variations into 3 main patterns (tab XXI).

Matejeik (2003) dealt with the variation in the formation of median nerve in 100 brachial plexus focusing on the course and anastomosis and found forty two deviations in 32 cases (64%) and the deviations had occurred more frequently on the left side in 16 cases which were frequently anastomosis in character.

Saeed (2003) noted an unusual formation of the median nerve and the musculocutaneous nerve in left arm of Caucassian male cadaver where the median nerve showed

- The formation by fusion of three roots; two from the lateral cord, one from the medial cord.
- The variant of lateral root of the median nerve crossing anterior to the distal part of axillary artery.
- In distal ½ of the arm, a communicating branch from the median nerve extended to the musculocutaneous nerve.

Arora et al (2003) showed the median and musculocutaneous nerves communication at two sites (fig 18).

- The proximal trunk was 2.5cm in length and given off by the musculocutaneous nerve before the latter pierced coracobrachialis and crossed distally to join the median nerve about 4.6cm from the coracoid process of scapula.
- The distal trunk was 10.7cm in length and started from the median nerve about 12.4cm from the coracoid process, crossed distally to join the musculocutaneous nerve after the latter had pierced the coracobrachialis. From this site of its union with musculocutaneous nerve, the branches to brachialis were given off.

Koshy et al (2003) noticed that the brachial artery and the median nerve crossed behind the supracondylar process and fibrous arch then passed through a hole between them and the humerus, finally reached the front of the elbow. (fig 19)

Cheung JW, Shyu JF et al (2004) based on their dissection of wrist (the palmar cutaneous nerve) in 60 specimens observed the following

- In 88.3%, the nerve originated from the radial side of the median nerve with the average length of 1.4cm from the palmaris longus and ulnarward in 11.7%.

- Only in 5cases (4.1%), it was located at ulnar side and extended beyond the palmaris longus, the average distance being 0.3cm. It's mean point of origin was 3.2cm proximal to the distal wrist crease.
- The variations of the palmar cutaneous nerve in Lanz classification (tab XXII).

From these findings they concluded that ***"the longitudinal incision made 1cm on the ulnar side from the palmaris longus can avoid injury to the palmar cutaneous nerve during decompression for carpal tunnel syndrome".***

Nagata et al (2004) reported a case in which the lateral root of the median nerve was formed of only the middle trunk, C7 and did not include upper trunk C5, C6. The upper trunk continued as the musculocutaneous nerve, but did not participate in the median nerve. They also noted in cubital fossa that the nerve descended on pronator teres which had an additional head arising from the medial intermuscular septum. They suggested the relevance that the first branch from the median nerve to the forearm muscles was the union covered with the common ensheathing epineurium.

Wadhwa(2004) demonstrated a musculo-aponeurotic tunnel through which the median nerve, brachial artery were passing.

Beheiry (2004) found the median nerve variations while dissecting 60 arms of 30 preserved cadavers (30-67 years age) (tab XXIII).

Tatar et al (2004) found the innervation of coracobrachialis by the lateral root of median nerve.

Loukas M, Aqueelah H (2005) demonstrated different patterns of the communications between the median nerve and musculocutaneous nerve with respect to the point of entrance of musculocutaneous nerve into the coracobrachialis in 129 fresh frozen cadavers (tab XXIV)(fig20).

MUSCULOCUTANEOUS NERVE:

Appleton (1912) showed a complete absence of the cutaneous branch of the radial nerve to hand which was replaced by the musculocutaneous nerve.

Neidhardt et al (1968) stressed upon the surgical importance of the musculocutaneous nerve into the coracobrachialis.

Olson (1969) studied about the origin of lateral antebrachial cutaneous nerve and its anaesthesia for modified brachial plexus block.

Hollinshed (1982) found the fibers that should have to run through lateral root of median nerve failed to do so, but entered the musculocutaneous nerve and rejoined the median nerve.

Gherardi et al (1986) studied the morphometry of the musculocutaneous nerve.

Kosugi et al (1986) reasoned out the communication between the musculocutaneous and median nerves that an altered signaling between the mesenchymal cells and circulatory factors at the time of fusion of brachial plexus cords.

Bourne et al (1987) based on their discussion in 20 antebrachial specimens, localized the proximal lateral antebrachial cutaneous nerve emerging from the lateral aspect of biceps tendon at the level of inter epicondylar line.

Koizumi (1989) observed the musculocutaneous nerve and its supply to coracobrachialis in 240 human arms of which 27 arms selected for nerve fiber analysis and were grouped (tab XXV). They concluded that ***"the change in the course of musculocutaneous nerve is closely correlated with the change in the ratio of part innervated by Rmc to the part innervated by Rp".***

Iwamoto et al (1990) described the communication between the musculocutaneous and median nerves. The elements of median and musculocutaneous nerves were not affected by approximation of the communicating branch which consisted of the fibers from C5, C6 in all cases.

Kosugi et al (1992) demonstrated the branching pattern of the musculocutaneous nerve in Japanese in relation to supernumerary head of biceps brachii; they found that

- The communicating branch was in 43 /75 limbs = 57.3%
- The communicating branch ran from

  Musculocutaneous nerve to median nerve = 24 limbs

  Median nerve to Musculocutaneous nerve = 12 limbs

  Both direction = 5 limbs

  Any type of pattern = 2 / 43 limbs

Yang et al (1995) noted different types of innervation by the musculocutaneous nerve of biceps brachii, brachialis while dissecting 24 fresh frozen arms under operating microscope and classified these branches (tab XXVI).This knowledge helps in suturing the intercostal nerve to the motor branch of biceps brachii, brachialis for elbow flexion in brachial plexus injuries.

William et al (1995) noted the smaller lateral root of the median nerve whenever the communication existed between the musculocutaneous and median nerves.

Nakatani et al (1997) encountered three anomalies in which the musculocutaneous nerve not piercing the coracobrachialis of that two were

bilateral in 89 year old male, a common sheath of connective tissue containing musculocutaneous nerve, lateral cord of brachial plexus and the median nerve. After removal of sheath these nerves were completely seperate or the fusion remained partially.

Egleder WA Jr, Goldman (1997) dissected 54 cadaveric arms and noted

- The length of the connection between musculocutaneous nerve and median nerve = 36% =1.77cm
- The distance from the coracoid process to the musculocutaneous nerve = 0.46cm distal
- The distance from the coracoid process to the median nerve =1.91cm distal
- The musculocutaneous nerve's entrance to coracobrachialis = 4.99cm
- The musculocutaneous nerve's exit from coracobrachialis =7.5 cm
- The musculocutaneous nerve entered into biceps brachii at 11.66 cm

Song et al (2003) found an absence of musculocutaneous nerve where the whole lateral cord was joined to median nerve at two points; one at the level of the corocoid process and the other at the junction of remaining lateral cord and median nerve at 92mm away from the typical junction

Abhaya A et al (2003) noted the passage of nerves within the coraco brachialis i.e., the musculocutaneous and lateral root of median nerves

passed at 96mm from coracoid process. The branch to coracobrachialis from the musculocutaneous nerve was at 98mm from the tip of coracoid process, the lateral root did not give any branch within the muscle and no communication between them within the muscle or subsequent course (fig 21).

Necdet kocabiyik et al (2005) found an anomalous branch of musculo cutaneous nerve arising approximately 2.8cm above the distal end of deltoid tuberosity and passing inferiorly between the biceps and brachialis for about 12.6cm and joined the median nerve at 5.6cm above the interepicondylar line (fig 22).

ULNAR NERVE.

Fischer et al (1970) demonstrated the surgical anatomy of the dorsal cutaneous branch of the ulnar nerve.

Engber WD, Gmeiner JG (1980) studied the anatomy of the palmar cutaneous branch of the ulnar nerve on dissecting 21 cadaveric forearms, hands and they found out 3 classic and two variant of that emerging in the subcutaneous tissue ulnar side to the ring finger axis, the terminal branches supplying the hypothenar skin extending radially in the same axis. They stated that ***"An incision in line with the ring finger ray axis is an attempt to avoid injury to both ulnar and median palmar cutaneous nerves".***

Bonnel F, Vila RM (1985) studied the anatomy of the ulnar nerve in 50 hands and noted the classical configuration in 39, variations with respect to division in 11 cases in the areas of muscular innervation.

Fuss FK (1989) showed the lateral root of ulnar nerve in 56% of 158 brachial plexus and classified into different types (tab XXVII).

Konig et al (1994) explained the contents of Guyon's canal exiting through two distinct areas termed the deep distal hiatus and superficial distal hiatus. Also they noted the variant course of deep branch of ulnar artery in 74% and the ulnar artery passed distal to that space. Guyon imparted the importance of opening the roof of Guyon's space, but also the fibrous arcade of deep distal hiatus.

Don griot et al (2000) notified a communicating branch between the 4^{th} and 3^{rd} common digital nerves in the palm in 50 out of 58 cadaveric hands (tab XXVIII) (fig 23).In 2002, they classified the variations of the communication between the ulnar and median nerves in 26 cadavers (tab XXIX).

Malcic – Gurbuz J et al (2002) came across a variant sensory branch of the ulnar nerve supplying ulnar ½ of index, middle and ring finger; the communicating branch was absent; the distribution of the median nerve was normal.

Von Schroeder HP, Scheker LR (2003) redefined the anatomy, presence of arcade of struthers, its anatomic variations, potential sites of compression of the ulnar nerve in 11 fresh specimens.

- The arcade and intermuscular septum present in all cases.
- Better described as a fibrous canal with an average length of 5.7cm, its openings at either end were 3.9cm and 9.6cm proximal to the medial epicondyle.
- The structural components were 1.the fibrous tissue of the intermuscular septum 2.An internal brachial ligament 3.The deep fascia of triceps 4.An epimysium of triceps itself.
- In all specimens, the nerve had an hourglass indentation at the proximal opening.

AXILLARY NERVE

This nerve was rarely found to have variation.

Bogdanovic D, Ilic A (1972) described the morphology and topography of the axillary nerve with its clinical importance.

Loomer and Graham (1989) studied the anatomy of the axillary nerve under the following aspects in 12 autopsy subjects

1. Normal relationship of nerve.

2. Its proximity to structures dissected in the procedure.

3. The effects of these procedures.

They stated from their observation that ***"The axillary nerve arose immediately posterior to the coracoid process, conjoint tendon and crossed the inferolateral border of the subscapularis about 3-5mm medial to its musculotendinous junction and lied in intimate contact with the inferior capsule of the shoulder joint as its passes through the quadrangular space".*** This nerve should be visualized prior to dissecting the subscapularis tendon.

Kasai et at (1989) defined the difference between posterior cutaneous nerve of arm (Cbp), medial cutaneous nerve of forearm (Cbm) and intercosto-brachial nerve.

Tubbs RS et al (2001) studied the proximal segment of the axillary nerve (ANp) as it is difficult to identify without extensive dissection deep into the axilla in 30 cadavers and noted the ANp was consistently located within the lines passing between coracobrachialis, pectoralis minor and axillary artery. The ANp was routinely found 4cm distal to coracoid process of scapula.

Matejcik (2005) noted the axillary nerve with an atypical course i.e. beginning as the continuation of the posterior branch of the upper trunk in 1 (2%) out of 100 brachial plexus (fig 24)

RADIAL NERVE

This nerve rarely demonstrated the variations.

Mackinnon SE et al (1985) described the anatomical relationship between the lateral antebrachial cutaneous nerve and superficial branch of the radial nerve in 53 cadavers and 41 clinical dissections.

Richardson GA et al (1989) reported on congenital compression of the radial nerve by the constricting amniotic bands.

Branovacki et al (1998) found the innervation by the radial nerve in 60 paired forearms.

- The branch to the extensor digitorum and extensor carpi ulnaris arose from a common stem often with a branch to extensor digiti minimi.
- The branch to the extensor carpi radialis brevis arose from posterior interosseous nerve in 45%, superficial sensory branch in 25% and at the bifurcation of the posterior interosseous and superficial branch in 30%.
- The supinator had an average of 2-3 branches from posterior interosseous nerve.

Fleming et al (2004) dissected 20 upper limbs where the radial nerve entered the anterior compartment at a point within 5cm of junction of middle and distal 1/3rd of the line joining the lateral epicondyle of humerus to the most lateral point of acromian process of scapula.

MATERIALS OF THE STUDY

- 30 embalmed and preserved adult human cadavers.

METHOD OF THE STUDY

Cadaveric Study

The study was carried out in 30 embalmed and well preserved human cadavers of both sexes that were kept in for the teaching programme of undergraduate and post graduate medical students at the Department of Anatomy, Stanley Medical College, Chennai by conventional dissection method described in Cunningham's manual of Practical Anatomy.

The incisions were made as per Cunningham's description figure(10) (incisions 2,3,5). After reflecting skin, superficial fascia and deep fascia in each region the nerves were traced.

In the posterior triangle, after removing the fat and fascia of the triangle and also the fascia from the inferior belly of omohyoid, the muscle was turned up; the upper part of the brachial plexus was traced between the scalenus medius and anterior backwards to its roots. The supra scapular nerve and dorsal scapular nerve piercing the scalenus medius were traced deep to omohyoid and trapezius respectively. The long thoracic nerve was dissected from its origin from the back of roots of brachial plexus towards the axilla. The roots of brachial plexus were

dissected after reflecting or detaching the scalenus anterior. The dissection was proceeded down after cutting the middle third of clavicle. The clavicular head of pectoralis major was cut, then reflected to observe the lateral pectoral nerve where it pierced the clavipectoral fascia. The medial pectoral nerve was dissected as it entered the pectoralis major after piercing through the pectoralis minor.

After removing the connective tissue, fat and lymph nodes from the axilla, the contents were explored. The axillary artery, vein and cords of brachial plexus were defined. The median nerve medial to coracobrachialis, short head of biceps brachii and the musculocutaneous nerves were traced towards the deep surface of coracobrachialis muscle. In between the axillary artery and vein, the medial cutaneous nerve of forearm anteriorly and ulnar nerve posteriorly were traced. The radial and axillary nerves were examined as they proceeded posteriorly towards the quadrangular space. On the lateral surface of serratus anterior, the long thoracic nerve was examined as it was descending on it to supply.

The upper, lower subscapular and thoracodorsal nerve were examined after cutting the pectoralis minor, on the anterior surface of subscapularis.

The deltoid muscle was separated from the spine of scapula and turned downwards. The axillary nerve along with the posterior

circumflex humeral vessels through the quadrangular space and its branches to deltoid, teres minor, capsule of shoulder joint were identified. The radial nerve from posterior cord was dissected anterior to latissimus dorsi and teres major, posterolaterally between the parts of triceps after giving branches to long and medial head of triceps.

In the arm, the biceps brachii was lifted and the median, musculocutaneous nerves were studied. After dividing and reflecting the lateral head of triceps, the radial nerve was traced in the spiral groove along with its branches to medial head. And in the distal arm the branches to brachioradialis were examined at level of elbow joint. After pulling the brachioradialis, the termination of radial nerve was traced in between the origins of extensors and flexors, the superficial branch of radial nerve was examined towards distal where as the distal branch piercing the supinator was traced distally for its supply to the extensor muscles.

In the cubital fossa, the median nerve was examined as it passed through the pronator teres. The flexor carpi radialis, palmaris longus, pronator teres were cut and reflected before examining their innervation. The median nerve was separated from the deep surface of flexor digitorum superficialis and was traced proximally to identify its muscular

branches and anterior interosseous nerve. After incising the flexor retinaculum longitudinally along the third interosseous space, exploring the carpal tunnel, the median nerve was examined. The ulnar nerve was identified to the posterior compartment of arm and there-after to the back of medial epicondyle of humerus. The ulnar nerve was there-after examined after pulling flexor carpi ulnaris, and the latter's muscular branches were identified.

The palmaris brevis was removed and the superficial branch of ulnar nerve was dissected towards the digital branches. The deep branch was traced after removing fat from the medial side of wrist distal to ulnar styloid process and was followed in the palm. After separating the hypothenar muscles, incising and reflecting the tendons of flexor digitorum superficialis and flexor digitorum profundus along with the lumbricals, the nerve supply to these intrinsic muscles was defined.

OBSERVATION

The brachial plexus in 60 human cadaveric specimens were observed from the level of origin to the level of termination in the following aspects

- The formation of the trunks, divisions and cords.
- Their relation with the nearby structures viz., muscles, vessels.
- The various branches from supraclavicular and infraclavicular parts.
- The communication between the nerves.
- The course of the branches.
- The level of distribution.
- The number of branches.

Of these above mentioned parameters, only the median nerve showed 19 variations in seventeen specimens out of 60 specimens. The rest of the brachial plexus showed the classical normal anatomical descriptions. These variations of the median nerve were also not of the same, but different on various parameters. Even a single variant is not of the same character in different specimens. Hence every variant specimen of both right and left sides was photographed, labeled and described individually. The specimens showing the variations include Sp.No.1,2,8,9,13,18,24,27,30,38,41, 43,45, 46,48,51,55.

The median nerve was observed to show variations in the gross form on the following aspects.

- A variant formation of the median nerve.
- The communication with the musculocutaneous nerve.
- An anomalous relation with the brachial artery.
- The relation of the median nerve with an anomalous structures
- An anomalous innervation in the arm
- A high division of the median nerve and its relation with an anomalous vessels.
- The communication with the ulnar nerve.
- An anomalous sensory innervation of the digits.

Specimen no 1: The left palm was showing a communicating branch of 1mm thickness and 1.9cm length passing from ulnar nerve distally and laterally to join the 3rd common digital branch of the median nerve. This communication occurred at about 1.6 cm distal to the distal border of the flexor retinaculum and 2.7cm above the distal palmar skin crease.

Specimen no 2: The right upper limb was found to have the formation of the median nerve at the level of upper 1/3rd of arm in relation to the brachial artery. The length of the lateral root was 4.8cm and that of medial root 5.8cm. The medial root crossed the brachial artery from medial to its lateral

side to join the lateral root and thus forming the trunk of median nerve. The formation occurred at about 6.6cm from the tip of coracoid process of scapula.

Specimen no 8: The left upper limb revealed that the median nerve did not have its 3rd common digital branch, instead the ulnar nerve gave off this branch which took over the sensory innervation of adjacent sides of middle and ring fingers. The median nerve supplied only the radial 2 ½ fingers. There was no overlapping or communication between these branches.

Specimen no 9: In the right upper limb,the median nerve was crossing posterior to the brachial artery from lateral to its medial side. The level of crossing occurred at the middle of the arm about 7.5cm above the interepicondylar line of the humerus.

Specimen no 13: The left upper limb demonstrated a communicating branch extending from musculocutaneous to median nerves before the former had pierced the coracobrachialis muscle. The communicating branch was about 3.4cm in length and 3mm in thickness and this occurred at about 4.1cm from the tip of coracoid process of the scapula. The lateral root of median nerve was measuring about 2mm in thickness.

Specimen no 18: The left upper limb revealed that there was a long communicating branch of 6.5cm extending from musculocutaneous nerve at

5mm of its exit from the coracobrachialis muscle and joined with the median nerve at about 13.1cm from the formation of its trunk, in the middle 1/3rd of arm.

Specimen no 24: In the right upper limb, a communicating branch was observed in the arm proceeding obliquely from 4th common palmar digital branch of ulnar nerve to 3rd common digital branch of the median nerve. The communication was of 1.2cm in length and 2mm in thickness. That communication occurred at about 2.7cm below the distal border of the flexor retinaculum.

Specimen no 27: The right upper limb. A communicating branch of 3.1cm in length originated from the musculocutaneous nerve after the latter had pierced the coracobrachialis, then passed distally to join the median nerve. The communication was present in the middle 1/3rd of the arm at the level of insertion of coracobrachialis muscle and about 11.1cm above the interepicondylar line of the humerus.

Specimen no 30: In the right upper limb, The brachial artery was terminating into two branches at the junction of upper and middle 1/3rd of the arm at about 14.4cm above the interepicondylar line of the humerus, 13.4cm below the tip of coracoid process of the scapula. In the upper 1/3rd of the arm, the median nerve was passing lateral to the artery and in the middle

1/3rd, lateral to the radial artery and in the lower 1/3rd of arm, the median nerve crossed between these two terminal branches. The crossing happened at about 4.3cm above the interepicondylar line of humerus.

Specimen no 38: In the right upper limb, the median nerve after its formation, crossed posterior to the brachial artery. That crossing occurred at about 9.8cm above the inter epicondylar line at the junction of the middle and distal 1/3rd of the arm.

Specimen no 41: In the middle of the right arm, a distal communicating branch of 4.6cm extended from the musculocutaneous nerve to the median nerve at about 8.4cm from the tip of coracoid process of the scapula.

Specimen no 43: The right arm was demonstrating a communicating branch of 2.2cm length and 3mm diameter. That branch originated from the musculocutaneous nerve at about 4cm after the latter emerged from the coracobrachialis and proceeded downwards laterally to join with the median nerve. But the median nerve before receiving the connecting branch and along with the brachial artery passed through a fibrous arch extending from the site of insertion of the coracobrachialis to the medial intermuscular septum of arm.

Specimen no 45: In the left upper limb, a communicating branch of 1cm length extended from the musculocutaneous nerve at about 1cm after it

pierced the coracobrachialis and 6.8cm below the tip of the coracoid process where it joined the median nerve.

Specimen no 46: In the right upper limb, the medial root of median nerve was about 13.6cm in length and 4mm in thickness but the lateral cord of brachial plexus after giving the lateral pectoral branch, continued as lateral root of median nerve. This root was about 15.3cm in length and 5mm in thickness. That lateral root after providing branches to coracobrachialis, biceps brachii and brachialis united with the medial root and formed the median nerve. The formation of the median nerve occurred at 16.8cm below the tip of coracoid process of the scapula. The musculocutaneous nerve was absent.

Specimen no 48: The right arm was demonstrating a connecting branch of 1.8cm length and 5mm thickness. The connecting branch extended from the musculocutaneous nerve distal to coracobrachialis in middle 1/3rd of brachium towards the median nerve. The connection located at 11cm proximal to the interepicondylar line.

Specimen no 51: In the left upper limb, after the lateral pectoral nerve the lateral cord of brachial plexus was joined by the medial root of median nerve to form the trunk of the median nerve. About 0.7cm from the site of formation and the musculocutaneous nerve was given off. This variation was

found at about 1cm distal to the tip of coracoid process of scapula. The medial root measured about 2cm in length, 4mm in diameter. Accidentally when trying to define the site of formation of the median nerve, the median nerve got splitted.

Specimen no 55: The left upper limb demonstrated a median artery arising from the anterior interosseous artery just at apex of the cubital fossa. About 2.3cm from its origin, the artery accompanied the median nerve. In this case, the brachial artery divided into ulnar, common interosseous and radial arteries. This median artery along with median nerve passed within a common sheath. Both of them traversed deep to flexor retinaculum in the carpal tunnel forming a common digital artery which then divided into 2 digital arteries supplying thumb, radial side of index finger. Finally the artery joined with the ulnar to complete the superficial palmar arch, 1.7cm distal to the distal border of the flexor retinaculum. The median nerve bifurcated into medial and lateral branches in the forearm at about 7.6cm above the level of the radial styloid process.

The findings in all specimens were tabulated.

TOTAL NUMBER OF CADAVERS **30**

TOTAL NUMBER OF SPECIMENS **60**

NUMBER OF NORMAL BRACHIAL PLEXUS WITHOUT ANY VARIATIONS **43**

NUMBER OF VARIATIONS OF BRACHIAL PLEXUS

(In 17 specimens; 2 variations in each of two specimens) 19

I. The anomalous observations were tabulated according to various parameters.

S.NO	VARIATIONS	NO. OF SPECIMENS	SPECIMEN NO
I	Variant formation of median nerve	03(1-H, 2-L)	2, 46, 51.
II	Communication with the musculocutaneous nerve	07(1-P , 6-D)	13, 18, 27, 41, 43, 45, 48.
III	An anomalous relation with the brachial artery	03	09, 30, 38.
IV	Relation to anomalous structures.	01	43.
V	Innervation to arm muscles	01	46.
VI	High bifid median nerve with persistent median artery	01	55.
VII	Anomalous sensory innervation	01	08
VIII	Communication with the ulnar nerve.	02	01, 24

(H- High level, L- low level, P- proximal, D- distal)

I I. INCIDENCE OF VARIATIONS (chart I).

1	Total number of specimens studied	60
2	Total number of variations of all entity (In 17 specimens; 2 variations in each of two specimens)	19
3	Percentage of variation	31.67%

III. DISTRIBUTION OF VARIATIONS AND PERCENTAGE TO TOTAL SPECIMENS (chart II).

S.NO	VARIATION	TOTAL NO OF SPECIMENS	% TO TOTAL SPECIMENS
1	Variant formation of median nerve	03	5%
2	Communication with musculo cutaneous nerve	07	11.66%
3	Anomalous relation with the brachial artery	03	5%
4	Relation to anomalous structures	01	1.66%
5	Innervation to arm muscles	01	1.66%
6	High bifid median nerve with persistent median artery	01	1.66%
7	Anomalous sensory innervation	01	1.66%
8	Communication with the ulnar nerve.	02	3.33%

IV. PERCENTAGE OF EACH VARIATION AMONG THE TOTAL VARIATIONS (chart III).

Total number of variations = 19 (In 17 specimens).

S.NO	VARIATION	TOTAL NO OF SPECIMENS	% TO TOTAL VARIATIONS
1	Variant formation of the median nerve	03	15.79%
2	Communication with the musculocutaneous nerve	07	36.84%
3	Anomalous relation with the brachial artery	03	15.79%
4	Relation to anomalous structures	01	5.26%
5	Innervation of the arm muscles	01	5.26%
6	High bifid median nerve with persistent median artery	01	5.26%
7	Anomalous sensory innervation	01	5.26%
8	Communication with the ulnar nerve.	02	10.53%

V. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart IV).

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Variant formation of the median nerve	3	5%	15.79%

Va. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart IV a)

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
High level formation of the median nerve	1	1.66%	5.26%

Vb. chart IV b.

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Low level formation of the median nerve	2	3.33%	10.53%

VI. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart V).

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Communication with the musculocutaneous nerve	7	11.66%	36.84%

VI a. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart V a).

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Proximal communication	1	1.66%	5.26%

VI b. chart V b.

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Distal communication	6	10%	31.58%

VII. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart VI)

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Anomalous relation with the brachial artery	3	5%	15.79%

VII. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart VII).

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Relation with anomalous structures	1	1.66%	5.26%

IX. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart VIII).

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Innervation of arm muscles.	1	1.66%	5.26%

VIII. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart IX).

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
High bifid median nerve with persistent median artery.	1	1.66%	5.26%

X. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart X).

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Anomalous sensory innervation	1	1.66%	5.26%

IX. PERCENTAGE OF THE VARIATION IN THE TOTAL SPECIMENS AND TOTAL VARIATIONS (chart XI).

VARIATION	NO. OF THE VARIATION	PERCENTAGE IN THE TOTAL SPECIMENS	PERCENTAGE AMONG THE VARIATIONS
Communication with the ulnar nerve	2	3.33%	10.53%

XI. The average length of the connecting branch between the median and the musculocutaneous nerves: 3.22cms (chart XII).

SPECIMEN NO.	LENGTH IN CM.
13	3.4
18	6.5
27	3.1
41	4.6
43	2.2
45	1.0
48	1.8

DISCUSSION

The various gross anatomical anomalies found in 60 adult human cadaveric specimens were analyzed, tabulated and computed depending on various parameters. They were compared with the similar studies worked out by experts in the past and were discussed.

I. Variant formation of the median nerve.

Buch (1964) reported the high level formation of the median nerve and the musculocutaneous nerve originated from median nerve in 6%

Hollinshed (1982) found that the lateral root entered the musculo cutaneous nerve and rejoined the median nerve.

Roberts WH (1992) defined various levels of formation of median nerve in the lower 1/3rd of shoulder.

Jakubowicz (2000) showed low level fusion of the two roots of median nerve as well as accessory heads of coracobrachialis, biceps brachii.

Vyshnepol'skii Alu et al (2001) reported a rare variant of low level of formation of median nerve at the junction of middle and lower 1/3 rd of brachium.

Uysal et al (2003) observed the distal formation of median nerve in 8.5% specimens.

Matejcik (2003) noted the formation of median nerve in the lower ½ of the arm unilaterally in 6 out of 50 specimens (12%).

The present study's (2006) incidence regarding the low level formation of median nerve is 3.33% and the high level formation of the median nerve with the musculocutaneous nerve originated from the median nerve is 1.66%

HIGH LEVEL FORMATION OF THE MEDIAN NERVE

(Chart XIII)

BUCH	6%
MY STUDY	1.66%

DISTAL FORMATION OF THE MEDIAN NERVE (chart XIV)

MATEJCIK	12%
UYSAL	8.5%
PRESENT STUDY	3.33%

II. Communication between the median and the musculocutaneous nerves:

Kosugi et al (1992) revisited his previous report and gave the incidence of the connection as 57.3%.The connection from the musculocutaneous to median nerve in 24 out of 43 limbs showed the incidence of 55.8%.

William et al (1995) in Gray's Anatomy described the smaller lateral root of median nerve whenever the communication existed.

Kaus (1995) demonstrated bilateral communication in one human cadaver.

Egleder et al (1997) measured the average length of communication in 36% specimens as 1.77cm.

Venieratos et al (1998) classified the communication between the musculocutaneous nerve, median nerve and found the incidence of

i.proximal communication (9/22 specimens) – 40.9%.

ii.distal communication (10/22) – 45.4%.

Prasada Rao (2000) showed the communication in 8/24 specimens (33.3%).

Basar et al (2000) estimated the length of communicating branch as 8cm and width as 3mm.

Choi et al (2002) reported the incidence of type 1 as 19.2% and type 2 as 72.6%.

Matejcik (2003) noted the communication in 6 cases out of which 4 were (66.6%) high at the level of shoulder.

Uysal (2003) reported the incidence of communication as 1%.

Asli aktan (2000) found the communication in 5/48 specimens (10.4%). The mean length was 5.5 +/- 2.5cm.

Beheiry (2004) showed the communication in 3/60 specimens (5%)

Loukas et al (2005) made the incidence for proximal communication as 45%; The Distal communication as 35%.

The present study's (2006) total incidence of communication is 11.66%. (Proximal communication 1.66%, distal communication 10%).

The patterns and incidence of communication between the median and musculocutaneous nerves in comparison with the previous studies:

A. As per Venieratos et al's classification:

Type I - 1 - 1.66%

Type II - 6 - 10%

B. As per Choi et al's classification:

Unilateral - 7 / 30 cadavers - 23.33%

C. As per Loukas et al's classification:

Type I - 1 / 60 - 1.66%

Type II - 6 / 60 - 10%

D. As per Kosugi's classification:

Type I - 7 / 60 - 11.66%

COMMUNICATION BETWEEN THE MEDIAN AND MUSCULOCUTANEOUS NERVES (chart XV)

KOSUGI	55.8%
PRASADA RAO	33.3%
CHOI ET AL (II)	72.6%
UYSAL	1%
BEHEIRY	5%
ASLI AKTAN	10.4%
PRESENT STUDY	11.66%

PROXIMAL COMMUNICATION BETWEEN THE MEDIAN AND MUSCULOCUTANEOUS NERVES (chart XVI)

VENIERATOS ETAL	40.9%
MATEJCIK	66.6%
LOUKAS ETAL	45%
PRECENT STUDY	1.66%

DISTAL COMMUNICATION BETWEEN THE MEDIAN AND MUSCULOCUTANEOUS NERVES (chart XVII)

VENIERATOS ETAL	45.4%
LOUKAS	35%
PRECENT STUDY	10%

Comparing with Beheiry's, the present study shows significantly high level of incidence. On considering the length of communication, my findings show high value than Egle der et al.

III. Anomalous relation to the brachial artery:

Adachi (1928) described an association of abnormalities of upper limb vessels with neural variations.

Grant (1980) noted the incidence of the brachial artery passing anterior to the median nerve was 13% and the high termination of brachial artery with the median nerve crossing between the branches as 5%.

Haviarova et al (2001) reported that the brachial artery passing through the median nerve in front of it along its entire course in 82.8% of 1000 population.

The present study (2006) showed that the incidence as 5%

IV. Relation of the median nerve with anomalous structures:

Koshy et al (2003) reported that the brachial artery and the median nerve crossing behind the supracondylar process and fibrous arch in the arm.

Elnaggar et al (2004) reported on variant slender tendon from coracobrachialis after its incertion crossing anterior to median nerve, brachial artery as an aponeurotic expansion to medial epicondyle of humerus.

Wadhwa (2004) reported a musculoaponeurotic tunnel in the arm through which median nerve and brachial artery.

The present study (2006) reveals the incidence as 1.66%

V. Anomalous innervation of the arm muscles by the median nerve:

Gumusalan et al (1998), Tatar et al (2004) reported that the coracobrachialis was supplied by the lateral root of median nerve.

Gumuburun et al (2000) demonstrated absence of musculocutaneous nerve and innervation of muscles of the arm by the median nerve.

Prasada Rao (2000) noticed absence of musculocutaneous nerve where the median nerve supplied the muscles of arm (8%).

Mahakkonukrauh and sumsoarp (2002) described a branch from the site of junction of distal communicating branch with the musculocutaneous nerve.

Song et al (2003) showed the median nerve innervating the muscles of arm where the lateral cord joined as a whole with median nerve twice and also absence of the musculocutaneous nerve.

Beheiry (2004) reported muscular branches to arm muscles from lateral root of median nerve in 1/60 specimens (1.7%).

The present study's (2006) incidence is 1.66%. The incidence of my study exactly fix with that of Beheiry.

THE MEDIAN NERVE INNERVATION TO THE

ARM MUSCLES (chart XVIII).

BEHEIRY	1.7%
PRESENT STUDY	1.66%

VI. High division of the median nerve with persistent median artery.

Lanz (1977) described the high division of median nerve as group III among the median nerve variations.

Chalmers (1978) noted that the median artery passing with median nerve deep to flexor retinaculum and through carpal tunnel.

Kornberg et al (1983) reported on a high division of median nerve in association with median artery and transligamentous three thenar branches.

Amadio (1987) showed radial half of the bifid median nerve passing through a separate compartment within the flexor ratinaculum and giving rise to motor and sensory branches to thumb, which later rejoined distal to the flexor ratinaculum.

Srivastava (1990) showed the median artery splitting the median nerve into two roots in the forearm in 2/134 upper limbs (1.5%).

Ahn et al (2000) showed the incidence of median artery as 0.6% and high division of median nerve 0.3%.

Propeck et al (2000) found the high bifid median nerve in 2/10 cadavers (20%).

Takami (2001) reported high division of median nerve with the ulnar nerve passing through a separate compartment within the flexor ratinaculum.

The present study (2006) shows the incidence of 1.66%.

The present incidence is slightly higher than that of Srivastava and significantly higher than that of Ahn et al.

HIGH BIFID MEDIAN NERVE (chart XIX).

SRIVASTAVA	1.5%
AHN ET AL	0.3%
PROPECK ET AL	20%
PRESENT STUDY	1.66%

VII. Pattern of sensory innervation of hand:

The present study's (2006) observation is rarely reported by the experts previously.

VIII. The communication with the ulnar nerve:

Crutchfield et al (1980) stated that the median – ulnar nerve communication occurring in 28% of general population.

Meals et al (1982) found a communication between 3rd and 4th common digital nerves in about 80% of specimens.

Ferrari, Gilbert (1991) demonstrated the communication lying > 4mm distal to the flexor retinaculum in 50% and extending from ulnar nerve distally to join 3rd common digital nerve.

Bas et al (1999) showed the incidence of the communication as 67% (20/30).

Dongriot et al (2000) noticed the communication in 44/58 hands and in 90% the branch passed in the middle 1/3rd of palm of hand and showed type 1 as a dominant.

Olave (2001) found the incidence of this communication as 96.4% in males and as 14.8% in females.

The present study (2006) shows the incidence as 3.33%

COMMUNICATION BETWEEN THE MEDIAN AND THE ULNAR NERVES IN THE PALM (chart XX).

BAS ET AL	67%
DONGRIOT ET AL	75.86%
PRESENT STUDY	3.33%

CONCLUSION

The knowledge of Anatomy in defining the normal structure as well as the variation in each region based on various parameters is always valuable for clinical application.

From my study, I noted the variations of brachial plexus especially the median nerve in most of the specimens on different aspects consisting of 1. The high level as well as low level formation of the median nerve 2. The median nerve was having a communication with the musculocutaneous nerve 3. The median nerve was passing behind or between the branches of the brachial artery 4. The median nerve was passing deep to the anomalous fibrous arch in the arm 5.the median nerve was supplying anterior compartment muscles of the arm 6. The median nerve was associated with the persistent median artery and terminated in the forearm 7. The median nerve was showing a communication with the ulnar nerve in the palm 8. The median nerve was supplying only the radial 2 ½ fingers.

These variations were also reported in the previous studies as a common entity, but the incidence might be different. The previous experts had done these studies in large number of specimens and I am yet to do in more number of specimens. Anyhow the common variation what I found was also

noted as a common variant by the experts. So the knowledge of these variations should be kept in mind during surgeries because these are the regions which are approached quiet frequently by the general surgeons, plastic surgeons, oncologists and anaesthesiologist.

I conclude by saying that ***"Among the brachial plexus, the median nerve shows variations frequently on various aspects. So as an Anatomist, it is my duty to stress upon the knowledge of this to the surgeons while performing surgeries and also to the physicians while interpretating unusual clinical presentations".***

TABLE I

NEURAL ANASTOMOSIS IN THE FETUSES

(VASICKOVA)

Type I	**Crossed over the axillary, lower subscapular nerves behind radial nerve**
Type II	**Penetrated the brachial plexus separating the radial nerve into 2 roots**
Type III	**Passed more ventrocaudal level of brachial plexus.**

TABLE II

STAGES IN FORMATION OF MICROVESSELS

1	**Prevascular**	**3 months of gestational age**
2	**Formation of neuro-muscular connections**	**3 – 5 month of gestational age**
3	**Developed stage**	**2^{nd} half of embryogenesis**

TABLE III

TYPES OF BRACHIAL PLEXUS (ATOJI)

Type I	**Cranial and caudal ventral divisions**	**MCN , median nerve, ulnar nerve**	**67.3%**
Type II	**Caudal ventral division of C8 – T1**	**Proximal muscular rami of MCN emerged from MN, UN.**	**19.2%**
Type III	**Cranial ventral ---------- Caudal ventral ----------**	**Proximal muscular rami Ulnar nerve**	**11.6%**
Type IV	**Quiet different from I and III**	**----------**	**1.9%**

- **MCN = Musculocutaneous nerve**
- **MN = Median nerve**
- **UN = Ulnar nerve**

TABLE IV

VARIATIONS OF VENTRAL ROOTS OF BRACHIAL PLEXUS

ROOTS OF BRACHIAL PLEXUS	INCIDENCE
C5, C6, C7, C8, T1	77%
C4, C5, C6, C7, C8, T1	21.7%
C4, C5, C6, C7, C8, T1, T2	1 case
C5, C6, C7, C8	1 case

- C6, C7 ----greatest diameter
- C5 ----- smallest diameter
- C6, C7 ----- Largest --- 79%
- C5 ------ Dorsal scapular nerve ---- 75.8% (110 BP)
- C5, C6, C7 –Lateral thoracic nerve ---- 76%

TABLE V

VARIATIONS OF MIDDLE TRUNK OF BRACHIAL PLEXUS

1	Increase in thickness of trunk	3.5 times
2	Increase in size of croo-sectional area of fascicle	3.2 times
3	Increase in number of fascicle	59%
4	Decrease in index of fascicular area	11%

TYPES OF BRACHIAL PLEXUS

Type I	C4 – T1 nerves	26.1%
Type II	C5 - T1 nerves	73.2%
Type III	C5 – T2 nerves	0.7

TABLE VI

(BUDAK)

I	**Martin – Gruber anastomosis**	**17.5% (19 specimens)**
	Bilaterally	**73.6% (14 cases)**
II	**Ulnar- median anastomosis**	**0%**
	Connection within abductor pollucis brevis	**73.1%**
	1st dorsal interossei	**20.8%**
	Abductor digiti minimi	**14.3%**

TABLE VII

SUPRA SCAPULAR NERVE FORMATION (YAN ET AL)

From C4, C5, C6	**2 cases**
Received a communicating branch between C4, C5 and C6	**3 cases**
From C5	**1 case**
From C5, both elements of C6	**3 cases**
From anterior elements of C6	**3 cases**

TABLE VIII

NEUROTISATION OF MCN WITH MPN (HANSASUTA)

1	**The mean distance between MPN and proximal part of MCN**	**37% of MPNs ; 15mm (too short)**
2	**The MPN pierced the pectoralis minor**	**80%**
3	**The cross- sectional area of MCN**	**2.5 times larger than MPN**

- **MCN - Musculocutaneous nerve.**
- **MPN - Medial pectoral nerve**

TABLE IX

VARIATIONS OF BRACHIAL PLEXUS

S.NO	PART	CASES	INCIDENCE
1	**Trunk**	**8**	**34.8%**
2	**Terminal branch**	**8**	**34.8%**
3	**Brachial plexus tract**	**1**	**4.3%**
4	**Collateral branch**	**1**	**4.3%**
5	**No anomalies**	**5**	**-**
6	**C4 contribution**	**-**	**30.4%**
7	**Low source of MCN**	**2**	**8.7%**

TABLE X

VARIATIONS OF BRACHIAL PLEXUS FORMATION

(UYSAL ET AL)

S.NO	VARIATION	INCIDENCE
1	C5 – T1 roots	71.5%
2	Prefixed type	25.5%
3	Post fixed type	2.5%
4	C2 AND T2 joined	0.5%
5	No inferior trunk	9%
6	No superior trunk	1%
7	Roots of median nerve joining in the distal part of arm	8.5%
8	Axillary nerve separated from the posterior division of superior trunk	2.5%
9	Communication between median and musculocutaneous nerves.	1%

TABLE XI

VARIATIONS OF BRACHIAL PLEXUS

	VARIATION	OCCURRENCE
Type	**Pre fixed type**	**26 cases – 47.3%**
	Post fixed type	**1 case**
	No anomaly	**9 cases**
Number	**143 anomalies**	**46 cases – 83.6%**
	One anomaly	**11 cases**
	2 or more anomalies	**35 cases**
Side	**Left side**	**41.2%**
	Bilateral	**33.6%**

- **Axillary nerve was a continuation of posterior branch of superior trunk.**

TABLE XII

GROUP	VARIATIONS
1	**Variation in the course of thenar branch.**
2	**Accessary branch at the distal portion of the carpal tunnel.**
3	**High division of the median nerve.**
4	**Accessary branch proximal to carpal tunnel.**

TABLE XIII

S.NO	NO OF SPECIMENS	INCIDENCE	FINDINGS.
1	9	45%	3 terminal branches to APB, OP, FPB.
2	6	30%	2 branches., 1 to APB, other to OP.
3	5	25%	4 other patterns with either 2,3 (or) 4 branches

- **APB = Abductor Pollucis Brevis.**
- **OP = Opponens Pollucis.**
- **FPB = Flexor Pollucis Brevis.**

- **ACCESSARY THENAR BRANCH ---15 Specimens**

75% → 25% arose from 1st common digital nerve.

Or

50% from the radial proper digital nerve to thumb.

TABLE XIV

TYPES OF MEDIAN AND MUSCULOCUTANEOUS NERVES

(LE MINOR)

TYPES	DESCRIPTION
I	No connection between both nerves.
II	Some fibers of lateral root joined medial root forming main trunk, but remaining of the lateral root ran in musculocutaneous nerve leaving it after a distance to join the main trunk of median nerve.
III	The lateral root from lateral cord ran in musculocutaneous nerve leaving it after a distance to join the main trunk of median nerve
IV	The fibers of MCN united with lateral root and after some distance, the MCN was given off from median nerve.
V	The MCN was absent and ran within the median nerve.

- **MCN - Musculocutaneous nerve.**

TABLE XV

MEDIAN AND ULNAR NERVE COMMUNICATION

1	**50%**	**It laid > 4mm distal to flexor retinaculum**
2	**25%**	**Within 4mm of distal edge of flexor retinaculum.**
3	**25%**	**Under the flexor retinaculum.**

TABLE. XVI

CLASSIFICATION OF MARTIN – GRUBER ANASTOMOSIS.

TYPE	INCIDENCE	DESCRIPTION (motor branch)
1	**60%**	**From MN to UN supplying median muscles.**
2	**35%**	**From MN to UN supplying ulnar muscles.**
3	**3%**	**From UN to MN supplying median muscles**
4	**1%**	**From UN to MN supplying ulnar muscles**

- **MN = Median Nerve.**
- **UN = Ulnar Nerve.**

TABLE.XVII

CLASSIFICATION OF MARTIN – GRUBER ANASTOMOSIS.

TYPE	NO: OF ARM	PATTERN (communication)
1a	13	Between Anterior Interosseous Nerve and Ulnar Nerve.
1b	1	Between Median Nerve and Ulnar Nerve.
2	8	Between the muscular branches of Flexor Digitorum Profundus.
3	1	Combination of type1a or 1b and 2.

TABLE XVIII

DISTRIBUTION PATTERN OF MUSCULAR BRANCH OF MEDIAN NERVE.

TYPE	DISTRIBUTION	INCIDENCE
I.	Branch to superficial head of FPB, APB, OP.	50%
II.	Branch only to APB, OP.	40%
III.	Branches to APB, OP, FPB and to APB, OP and to APB,FPB.	10%

- FPB = Flexor Pollucis Brevis
- APB = Abductor Pollucis Brevis
- OP = Opponens Pollucis.

The types I, II were further subdivided according to the site, direction and the number of individual branches.

TABLE XIX

COMMUNICATION BETWEEN THE

MUSCULOCUTANEOUS NERVE AND MEDIAN NERVE

TYPE	FINDINGS	NUMBER (out of 22)
1	Communication was proximal to the entrance of MCN into coracobrachialis	9
11	Communication was distal to the coracobrachialis	10
111	The nerve and the communication did not pierce the muscle.	3

- MCN = Musculocutaneous Nerve.

TABLE XX

CLASSIFICATION OF BERRETTINI BRANCH IN RELATION TO THE

DISTAL MARGIN OF THE TRANSVERSE CARPAL LIGAMENT (TCL)

GROUP	NO: OF HANDS	DESCRIPTION
1	12	Communication in an oblique course from UN toMN originating > 4mm above TCL.
11	16	Communication parallel to TCL.
111	53	Communication in oblique course from UN to 3rd common digital nerve originating below TCL.
1V	0	Atypical communication.

- TCL - Transverse carpal ligament
- UN - Ulnar nerve
- MN - Median nerve

TABLE XXI

TYPES OF COMMUNICATION

TYPE	DESCRIPTION	NO:OF ARMS	INCIDENCE
1	Fusion of both the nerves.	14	19.2%
11	Presence of supplementary branch between both nerves.	53	72.6%
111	Two branches.	5	6.8%

- **The type 11 → 11a → Single root from musculocutaneous nerve contributed to the connection = 51arms = 69.9%**

  → 11b → Two roots from musculocutaneous nerve.

  = 2 arms =2.7%

- **A combination of pattern 1 , 11a in one =1.4%**
- **Overall incidence = 33%**

TABLE XXII

CLASSIFICATION FOR THE VARIATIONS OF

PALMAR CUTANEOUS BRANCH OF MEDIAN NERVE

GRADE	INCIDENCE
0	31.7%
1	40%
2	15%
3	0%
4	13.3%

TABLE XXIII

VARIATIONS OF MEDIAN NERVE IN THE ARM

NO: OF ARMS	INCIDENCE	VARIATION
1 / 60	1.7%	Muscular branch to brachialis, branch from its lateral root to biceps brachii; absent MCN; A branch from lateral cord of brachial plexus to CBM.
3 / 60	5%	Communicating branch between the median nerve and MCN.

- MCN = MusculoCutaneous Nerve
- CBM = CoracoBrachialis Muscle.

TABLE XXIV

PATTERNS OF COMMUNICATION OF BETWEEN

THE MEDIAN NERVE AND MUSCULOCUTANEOUS NERVE

TYPES	NO OF CADAVERS	INCIDENCE	PATTERN
I	54	45%	The connection was proximal to the entry
II	42	35%	The connection was distal to the entry.
III	11	9%	The MCN did not pierce the muscle.
IV	9	8%	The connection was proximal and an additional connection distally.

TABLE XXV

GROUPS OF BRANCHES OF MUSCULOCUTANEOUS NERVE

SUPPLYING CORACOBRACHIALIS

GROUP	NAME	ORIGIN	RELATION	SUPPLY
I	Rmc	Constant in appearance	-	Largest area of CBM.
II	Rp (deep branch)	Constant in appearance.from the middle trunk.	Dorsal to medial cord.	Proximal deep part of the CBM.
III	Rs (superficial branch)	5 / 27 cases, from ventral part of the middle trunk.	Ventral to medial cord.	Proximal ventral part of CBM

- **CBM = Coracobrachialis muscle.**

TABLE XXVI

THE CLASSIFICATION OF INNERVATION OF BICEPS BRACHII.

GROUP	NO OF ARMS	PATTERN
I	20	Common primary motor branch bifurcating to supply two heads.
II	2	Two separate primary branches from main trunk, supplying individually each head.
III	2	Type I + distal additional motor branch to the common belly.

The motor branches to biceps brachii existed from musculocutaneous nerve at 119mm distal to the coracoid process.

CLASSIFICATION OF INNERVATION OF BRACHIALIS

GROUP	NO OF ARMS	PATTERN
I	23	Single primary motor branch
II	1	Two separate primary motor branches

The motor branches to brachialis were 170mm distal to coracoid process.

The motor branches to biceps brachii, brachialis lied proximally from their point of exit from the main trunk at mean distance of 44mm, 53mm respectively.

TABLE XXVII

TYPES OF LATERAL ROOT OF ULNAR NERVE

ACCORDING TO ITS RELATION.

Type I	**Lateral root accompanied by fibers of the median nerve**
Type II	**Lateral root may run separately.**

ACCORDING TO ITS COURSE.

(Where it crossed the median nerve)

Type A	**Small minority of fibers of the median nerve ran behind the ulnar fibers.**
Type B	**All median fibers were in front of the ulnar fibers.**

- **The relation : 56:44% between the ulnar nerve with / without a lateral root.**
- **The term “median loop” / “ulnar loop” suggested for specially with a lateral root.**

TABLE XXVIII

COMMUNICATION BETWEEN THE 4TH, 3RD COMMON DIGITAL NERVES

44hands	Originated proximally from 4th CDN to join 3rd CDN distally
4 hands	Traversed perpendicularly between 3rd , 4th CDN
2 hands	Left the 3rd CDN proximally to join the 4th CDN distally

- In 90% of the hands, the communicating branch crossed over in the middle 1/3rd of palm of the hand.

TABLE XXIX

TYPES OF VARIATION OF COMMUNICATION BETWEEN ULNAR AND MEDIAN NERVES

TYPE I	Connecting branch originated proximally from the 3rd CDN to join distally 4th (UDN), 5th (RDN) CDN.
TYPE II	Connecting branch traversed perpendicularly between 3rd, 4th CDN with crossing over of nerve fibers.

- CDN - Common digital nerve.
- UDN - Ulnar digital nerve
- RDN - Radial digital nerve

THE SPECIMEN PARTICULARS.

Specimen No.	Normal	I	II	III	IV	V	VI	VII	VIII
1	-	-	-	-	-	-	-	-	*
2	-	***l**	-	-	-	-	-	-	-
3	*	-	-	-	-	-	-	-	-
4	*	-	-	-	-	-	-	-	-
5	*	-	-	-	-	-	-	-	-
6	*	-	-	-	-	-	-	-	-
7	*	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	*	-
9	-	-	-	*	-	-	-	-	-
10	*	-	-	-	-	-	-	-	-
11	*	-	-	-	-	-	-	-	-
12	*	-	-	-	-	-	-	-	-
13	-	-	***p**	-	-	-	-	-	-
14	*	-	-	-	-	-	-	-	-
15	*	-	-	-	-	-	-	-	-
16	*	-	-	-	-	-	-	-	-
17	*	-	-	-	-	-	-	-	-
18	-	-	***d**	-	-	-	-	-	-
19	*	-	-	-	-	-	-	-	-
20	*	-	-	-	-	-	-	-	-
21	*	-	-	-	-	-	-	-	-
22	*	-	-	-	-	-	-	-	-
23	*	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	*
25	*	-	-	-	-	-	-	-	-
26	*	-	-	-	-	-	-	-	-
27	-	-	***d**	-	-	-	-	-	-
28	*	-	-	-	-	-	-	-	-
29	*	-	-	-	-	-	-	-	-
30	-	-	-	*	-	-	-	-	-
31	*	-	-	-	-	-	-	-	-
32	*	-	-	-	-	-	-	-	-
33	*	-	-	-	-	-	-	-	-
34	*	-	-	-	-	-	-	-	-
35	*	-	-	-	-	-	-	-	-
36	*	-	-	-	-	-	-	-	-
37	*	-	-	-	-	-	-	-	-
38	-	-	-	*	-	-	-	-	-
39	*	-	-	-	-	-	-	-	-
40	*	-	-	-	-	-	-	-	-

Specimen No.	Normal	I	II	III	IV	V	VI	VII	VIII
41	-	-	***d**	-	-	-	-	-	-
42	*	-	-	-	-	-	-	-	-
43	-	-	***d**	-	*	-	-	-	-
44	*	-	-	-	-	-	-	-	-
45	-	-	***d**	-	-	-	-	-	-
46	-	***l**	-	-	-	*	-	-	-
47	*	-	-	-	-	-	-	-	-
48	-	-	***d**	-	-	-	-	-	-
49	*	-	-	-	-	-	-	-	-
50	*	-	-	-	-	-	-	-	-
51	-	***h**	-	-	-	-	-	-	-
52	*	-	-	-	-	-	-	-	-
53	*	-	-	-	-	-	-	-	-
54	*	-	-	-	-	-	-	-	-
55	-	-	-	-	-	-	*	-	-
56	*	-	-	-	-	-	-	-	-
57	*	-	-	-	-	-	-	-	-
58	*	-	-	-	-	-	-	-	-
59	*	-	-	-	-	-	-	-	-
60	*	-	-	-	-	-	-	-	-

***** = Present.

I - Variant formation of median nerve.

II - Communication with the musculocutaneous nerve

III - Anomalous relationship with the brachial artery

IV - Relation to anomalous structures

V - Innervation of arm muscles

VI - High bifid median nerve with persistent median artery

VII - Anomalous sensory innervation

VIII - Communication with the ulnar nerve

p - Proximal

d - Distal

h - High

l - Low

BIBLIOGRAPHY

1. ***Abhaya A, Khanna J and Prakash R*** - Variation of the lateral cord of brachial plexus piercing coracobrachialis muscle. J Anat Soc.India 2003; 52(2) : 168-170.

2. ***Adachi B*** – Das arterian- system der Japoner. Bd I Maruzen company Kyoto. 1928;197 – 372.

3. ***Ahmet Uzun., Sait Bilgic*** - Some variations in the formation of the brachial plexus in infants. Tr J of medical sciences. 1995; 29: 573.

4. ***Ahn DS., Yoon ES., Koo SH., Park SH*** – The prospective study of the anatomic variations of the median nerve in the carpal tunnel in Asians. Ann Plast Surg 2000 Mar; 44(3): 282-7.

5. ***Akila K, Kawashima T, Shimokowa T, Sato K, Sato T***- Cutaneous nerve to the subacromial region originating from the lateral pectoral nerve. Ann Anat. 2002 Jan; 184(1): 15-9.

6. ***Al – qattan MM. Ganter's muscle*** - An anatomical study of the accessory head of the flexor pollucis longus muscle. J Hand Surg (Br). 1996 Apr; 21(2): 269-70.

7. ***Amadio PC***- Bifid median nerve with double compartments within the transverse carpal ligament. J Hand Surg (Am). 1987 May; 12(3): 366-8.

8***. Appleton AB*** - A case of abnormal distribution of the musculocutaneous nerve with complete absence of the ramus cutaneous nerve radialis. J Anat Physiol 1912; 46: 89-94.

9. ***Arey L.B*** - Developmental Anatomy. A textbook of embryology In: The muscular system. 7th edn; W.B.Saunders Co. Philadelphia London. Pp430. 1966; 501-504.

10. ***Arora J., Kapur V., Suri R.K., Khan R.Q*** - Inter-communication between median and musculocutaneous nerves with dual innervation of Brachialis muscle- A case report. J Anat Soc India 2003; 52(1):66-68.

11. ***Asli Aktan Z., Lokman ozturk., Okan Bilge., Mehmet Asim ozer*** - Yelda Atamaz Pinar. Turk J Med Sci 2001; 31: 147-150.

12. ***Atoji Y, Suzuki Y, Sngimura M*** – The brachial plexus of the Japanese Serow. Anat Anz. 1987; 163(1): 25-32.

13. ***Bas H, Kleinert JM*** – Anatomic variation in sensory innervation of the hand and digits. J Hand Surg (Am). 1999 Nov; 24(6): 1171-84.

14. ***Basar R, Aldur MM, Celik HH, Yuksel M, Tascioglu AB*** – A connecting branch between the musculocutaneous nerve and median nerve. Morphologie. 2000 Sep; 84(266): 25-7.

15. ***Buch C***- On the variation in the method of innervation of the biceps muscle of the arm with special reference to branches from the musculocutaneous nerve and the median nerve . Anat Anz. 1964; 114: 131-140.

16. ***Beheiry EE*** – Anatomical variations of the median nerve distribution and communication in the arm. Folia Morphol (Warsz). 2004 Aug: 63(3):313-8.

17. ***Benassy J*** – A case of transposition of the musculo-cutaneous nerve upon the median nerve.Paraplegia. 1965 Nov; 3(3): 199-202.

18. ***Bisenkov NP, Popovich MI***- Individual variations in relations between the sympathetic trunk and brachial plexus. Vestn Khis Im II Grek. 1973 Jul; 111(7): 70-4.

19. ***Bogdanovic D, Ilic A*** – Morphology and topography of the axillary nerve and its clinical importance. Med glas. 1972 Nov; 26(11): 377-9.

20. ***Bonnel F*** – Microscopic anatomy of the adult human brachial plexus: an anatomical and histological basis for microsurgery. Microsurgery. 1984; 5(3): 107-18.

21. ***Bonnel F, Vila RM*** – Anatomical study of ulnar nerve in hand. J H and Surg (Br). 1985 Jun; 10(2): 165-8.

22. ***Bourne MH, Wood MB, Carmichael SW*** – Locating the lateral antebrachial cutaneous nerve. J H and Surg (Am). 1987 Sep; 12 (5 pt 1): 697-9.

23. ***Branovacki G, Hanson M, Cash R, Gonzalez M***- The innervation pattern of the radial nerve at the elbow and in the forearm. J Hand Surg (Br). 1998 Apr; 23(2): 167-9.

24. ***Brash JC*** – Cunningham's text book of anatomy 9th Edn. Oxford university press. 1953; pp 1067- 1085.

25. ***Budak F, Gonenc Z*** – Innervation , anomalies in the upper and lower extremities (an electrophysiological study). Electromyogr clin neurophysiol. 1999 Jun; 39(4): 231-4.

26***. Chalmers J*** – Unusual cases of peripheral nerve compression. The Hand.1978; 10: 168-175.

27. ***Cheung JW, Shyu JF, Teng CC, Chen TH, Su CH, Shyr YM, Wang JJ, Wu CW, Lui WY, Liu JC*** – The anatomical variations of the palmar cutaneous branch of the median nerve in Chinese adults.J Chin Med Assoc. 2004 Jan; 67(1): 27-31.

28. ***Choi D, Rodriguez – Niedenfuhr M, Vazquer T, Parkin I, Saundo JR***- Patterns of connections between the musculocutaneous and median nerves in the axilla and arm. Clin Anat . 2002 Jan; 15(1): 11-7.

29. ***Chuchkov kh*** – Branches of the supraclavicular portion of brachial plexus. Nauchni Tr Vissh med Inst Sofiia. 1963; 42:61-75.

30. ***Crutchfield CA, Gutmann L*** – Hereditary aspects of the median –ulnar nerve communication. J Neurol Neurosurg Psychiatry. 1980; 43(1): 53-5.

31. ***Cunningham DJ.*** Note on a connecting twig between the anterior division of the first and second dorsal nerves. J Anat Physiol. 1877; 11: 63-90.

32***. Dellon AL, Mackinnon SE*** – Musculo-aponeurotic variations along the course of the median nerve in the proximal forearm. J Hand Surg (Br). 1987 Oct; 12(3): 359-63.

33. ***Dongriot JP, Zuidam JM, Van kooten EO, Prose LP, Hage JJ*** – Anatomic study of the ramus communicans between the ulnar and median nerves. J Hand Surg (Am). 2000Sep; 25(5): 948-54.

34. ***Egleder WA Jr, Goldman M*** – Anatomic variations of the musculocutaneous nerve in the arm. Am J Orthop.1997; 26(11): 777-80.

35. ***El- Naggar MM, Al- Saggaf S*** – Variant of coracobrachialis muscle with a tunnel for the median nerve and brachial artery. Clin Anat. 2004 Mar; 17(2): 139-43.

36. ***Engber WD, Gmeiner JG*** – Palmar cutaneous branch of ulnar nerve. J Hand Surg (Am). 1980 Feb; 10(1): 69-76.

37. ***Fazan VPS, Amadeu AS, Caleffi AL, Rodrigues Filho OA***- Brachial plexus variation in its formation and main branches. Acta Cir Bras. 2003; vol 18 (sup 15):14-18.

38. ***Fenart R*** – Morphogenesis of the brachial plexus and its relation to the formation of the neck and the arm. Acta anat (Basel). 1958; 32(4): 322-60.

39. ***Ferner H*** – Der Nervus musculocutaneous, science verlaufs varietatien an oberarm and deren Bezichungen zur Entcoicklung eines caput tertium musculi bicipitis. Zeitschr Anat Ent Wicklung. 1938; 108: 567- 586.

40. ***Ferrari GP, Gilbert A*** – The superficial nastomosis in the palm of the hand between ulnar and median nerves. J Hand Surg (Br). 1991 Sep; 16(5): 511-4.

41. ***Fleming P, Leneham B, Sankar R, Folan***- Curran J, Curtin W – One third, two thirds: relationship of the radial nerve to the lateral intermuscular septum in the arm. Clin Anat. 2004 Jan; 17(1): 26-9.

42. ***Fischer L, Neidhardt JH, Comtet JJ, Morin A, Autissier JM*** – Surgical anatomy of the dorsal cutaneous branch of ulnar nerve. CR Assoc Anat. 1970 May; 147: 266-70.

43. ***Fischer L., Neidhardt JH., Tissor E, Spanta A***- Anatomical relation of scalenus muscle and brachial plexus relationships. Lyon med. 1971 Apr25; 225(8): 750-2.

44. ***Fuss FK*** – The lateral root of the ulnar nerve. Acta Anat (Basel). 1989; 134 (3): 199-205.

45. ***Gherardi R, Benair JP, Mussini JM, Hauw JJ*** – Morphometric study of the branches of the musculocutaneous nerve:Normal results. Arch Anat Cyto Pathol.1986; 34(5-6):261–7

46. ***Grant's*** method of Anatomy. 10th Edn. The Williams and Wilkins comp. 1980 May.

47. ***Gumusalan Y, Yazar F, Ozan H***- Variant innervation of the coracobrachialis and unusual course of the musculocutaneous nerve in man. Kaibogaku Zasshi.1998 Jun; 73(3): 269-72.

48. ***Gumusburun E, Adiguzel E*** – A variation of the brachial plexus characterized by the absence of the musculocutaneous nerve: A case report. Surg Radiol Anat. 2000; 22(1): 63-5.

49. ***Hansasuta A, Tubbs RS, Grabb PA*** – Surgical relationship of the medial pectoral nerve to the musculocutaneous nerve: a cadaveric study. Neurosurgery. 2001 Jan; 48(1): 203-6.

50. ***Harman B.***The anterior limit of the cervicothoracic visceral efferent nerves in man. J Anat Physiol. 1900; 34: 357-380.

51. ***Harris W*** – The true form of the plexus and its motor distribution. J Anat Physiol. 1904; 38: 399-442.

52. ***Haviarova Z, EI Falougy HAK, Kilingerova A*** – A typical course of the median nerve. Bratisl lek listy. 2001; 102(8): 372-373.

53. ***Hirasawa K*** – Untersuchungen iiber das periphere nervensystem, plexus brachialis und die nerven der oberen extremitat. Arb Anat. Inst kai serlichen univ Kyoto A2. 1931; 135-136.

54. ***Hollinshed WH***- Anatomy for surgeons. The back and limbs. 3rd Edn., Harper and Raw, Philadelphia, 1982.

55. ***Kosugi K, Mortia T, Yamashita H,***- Branching pattern of the musculocutaneous nerve 1 case possessing normal biceps brachii. Jikeakai Medical journal. 33: 63-71.

56. ***Ihunwo AO, Osinde SP, Mukhtar AV*** – Distribution of median nerve to the muscles of the anterior compartment of the arm. Cent Afr J Med. 1997 Dec; 43 (12): 359-60.

57. ***Iwamoto S, Kimura K, Takahashi Y, Konishi M*** - Some aspects of the communication branch between musculocutaneous nerve, median nerves in man. Okajimas Folia Anat Jpn. 1990 May; 67(1): 47-52.

58. ***Jakubowicz M, Ratajczak W***- Variation in the morphology of the biceps brachii and coracobrachialis muscles associated with abnormal course of blood vessels and nerves. Folia morphol (Warsz). 2000; 58(4): 255-8.

59. ***Kasai T, Chiba S, Snzuki T, Okuno Y*** – Morphological characteristics of the posterior brachial cutaneous nerve- a consideration of the development of cutaneous nerves in man. Kaiboguku zasshi. 1989 Aug; 64(4): 255-66.

60. ***Kaus M, Wotowicz Z*** – Communicating branch between the musculocutaneous and median nerves in human. Folia Morphol (Warsz). 1995; 54(4): 273-7.

61. ***Kerr AT*** – The brachial plexus of nerves of man, the variation in its formation and branches. American journal of Anatomy. 1918; 23: 285-395.

62. ***Kitayama Y, Tsukada S, Kurokawa M*** – High division of median nerve: Unusual anatomical variation. Ann. Plast Surg. 1985 Jan; 14(1): 74-6.

63. ***Koizumi M*** – A morphologic study on the coracobrachialis muscle. Kaibogaku Zasshi. 1989 Feb; 64(1): 18-35.

64. ***Konig PS, Hage JJ, Bloem JJ, Prose LP*** – Variations of the ulnar nerve and ulnar artery in Guyon's canal: a cadaveric study. J Hand Surg (Am). 1994 Jul; 19(4): 617-22.

65***. Kornberg M, Aulicino PL, Dupuy TE*** – Bifid median nerve with three thenar branches. J Hand Surg(Am).1983 Sep; 8(5pt1): 583-4.

66. ***Koshy S, Rabi S, Indrasingh I, Vettivel S*** – Two anatomical variations associated with potential vascular entrapment in the upper limb. Eur J Anat. 2003; 7(2): 97-100.

67. ***Kosuki K, Mortia T, Yamashita H*** – Branching pattern of the musculocutaneous nerve 1 case possessing normal brachial plexus. Jikeakai medical journal.1986; 33: 63-71.

68. ***Kosugi K, Shihata S, Yamashita H***- Supernumerary head of biceps brachii and branching pattern of the musculocutaneous nerve in Japanese. Surg Radiol Anat .1992; 14(2): 175-85.

69. ***Lanz U*** – Anatomical variations of the median nerve in the carpal tunnel. J Hand Surg (Am). 1977 Jan; 2(1): 44-53.

70. ***Lee HY, Chung IH, Sir WS, Kang HS, Lee HS, Ko JS, Lee MS, Park SS*** – Variations of the ventral rami of the brachial plexus. J Korean Med Soi. 1992 Mar; 7(1): 19-24.

71. ***Leibovic SJ, Hartings H 2nd*** – Martin – Gruber revisited. J Hand Surg (Am). 1992 Jan; 17(1): 47-53.

72. ***Le Minor JM*** - A rare variation of the median and musculocutaneous nerves in man. Arch Anat Histol Embryol. 1990; 73: 33-42.

73. ***Lenen D, Poureyus Y, Chardel P, Beal D, Lefevre C, Senecail B, Courtois B*** – Anatomical basis of neurotization of the median nerve in the hand by the radial nerve. Surg Radial Anat. 1991; 13(4): 271-5.

74. ***Lengele B, Dhem A*** – Unusual variations of the vasculonervous elements of the human axilla. Report of three cases. Arch Anat Histol Embryol. 1989; 72: 57-67.

75. ***Linell EA*** – The distribution of nerves in the upper limb with reference to variabilities and their clinical significance. Journal of Anatomy. 1921; 55: 79-112.

76. ***Loomer R, Graham B*** – Anatomy of the axillary nerve and its relation to inferior capsular shift. Clin Orthop Relat Res. 1989 Jun; 243: 100-5.

77. ***Loukas M, Aqueelah H*** – Musculocutanous and median nerve connection within, proximal and distal to the coracobrachialis muscle. Folia morphol (Warsz). 2005 May; 64 (2): 101-8.

78. ***Mackinnon SE, Dellon AL*** – The overlap pattern of the lateral antebrachial cutaneous nerve and the superficial branch of radial nerve. J Hand Surg (Am).1985 Jul; 10(4): 522-6

79***. Mahakkanukrauh P and Somasarp V*** – Dual innervation of brachialis muscle. Clinical anatomy. 2002; 15: 206-9.

80. ***Malcic – Gurbuz J, Ozdogmus O, Cavder S*** – Unusual anatomic variation of palmar sensory branches of the ulnar nerve: a case report. J Hand Surg (Am). 2002 Jan; 27(1): 147-9.

81. ***Mansat M*** – Surgical topographic anatomy of the brachial plexus. Rev Chin Orthop Reparatrice appar mot. 1977 Jan- Feb; 63(1): 20-6.

82. ***Matejcik V***- Anatomic deviations in the origin of the median nerve – Ro zhl chir. 2003 Oct; 82 (10): 526-8.

83. ***Matejcik V*** – Atypical course of nervus axillaries. Bratisl Lek Listy. 2005; 32 (4):216-7.

84. ***Matejcik V***- Variations of nerve roots of the brachial plexus. Bratisl Lek Listy. 2005; 106(1): 34-6.

85. ***Mc Farlane RM, Mayer JR, Hugill JV*** – Further observations on the anatomy of the ulnar nerve at the wrist. Hand. 1976 Jun; 8(2): 115-7.

86. ***Meals RA, Shaner M*** – Variation in the digital sensory patterns: a study of the ulnar- median nerve palmar communicating branch. J Hand Surg (Am). 1983 Jul; 8(4): 411-4.

87. ***Miller RA*** – Comparative studies upon the morphology and distribution of the brachial plexus. American journal of Anatomy. 1934; 54: 143-147.

88. ***Miranta DR*** – Identification of the brachial plexus perivascular space. Br J Anaesth. 1971 Jul; 49 (7): 721-2.

89. ***Mrvaljevic D, Dordevic- Cambar*** – Anastomosis of the musculocutaneous nerve in the region of upper arm

90. ***Mumford J, Morecraft R, Blair WF*** -- Anatomy of thenar branch of median nerve. J Hand Surg (Am). 1987 May; 12(3):361-5.

91. ***Naff N, Dellon AL, Mackinnon SE*** – The anatomical course of the palmar cutaneous branch of median nerve, including a description of its own unique tunnel. J Hand Surg (Br). 1993 Jun; 18(3): 316-7.

92. ***Nagata H, Hiramoto M, Horic K, Aizawa S*** – A case of median nerve descended on the surface of the pronator teres muscle. Kaibogaku Zasshi. 2004 Mar; 79(1): 25-30.

93. ***Nakashima T (Martin- 1763)*** – A anatomical study on Martin Gruber Anastomosis. Surg Radiol Anat. 1992; 15(3): 193-5.

94. ***Nakatani T, Mizukami S, Tanaka S*** – A rare case: The medial cord of the brachial plexus sandwiched between the axillary and superficial brachial arteries. Kaibogaku Zasshi. 1997 Apr; 72(2): 151-4.

95. ***Nakatani T, Tanaka S, Mizukami S***- Absence of musculocutaneous nerve with innervation of coracobrachialis , biceps brachii, brachialis and the lateral border of forearm by branches from the lateral cord of the brachial plexus. 1997; 191(3): 459-60.

96. ***Nakatani T, Mizukami S, Tanaka S*** – Three cases of the musculocutaneous nerve not piercing the coracobrachialis. Kaibogaku Zasshi. 1997 Jun; 72(3): 191-4.

97. ***Nebot – Cegarra J, Reina – dela Torre F, Perez – Berruezo J*** – Accessary fasciculi of the human pronator teres muscle; Incidence, morphological characteristics and relation to the median nerve. Anat Anz.1994 Jun; 176(3): 223-7.

98. ***Necdet kocabiyik, Bulent Yalcin, Fatih Yazar, Hasan ozan*** – An accessary branch of musculocutaneous nerve joining median nerve. Neuroanatomy. 2005; 4: 13-15.

99. ***Neidhardt JP, Morin A, Autissier JM, Latarjet M*** – Entrance of the musculocutaneous nerve in coracobrachial: Surgical applications. Lyon chir. 1968 Mar – Apr; 64(2): 268-76.

100. ***Olave E, Prates JC, Gabrielli C, Pardi P*** – Morphometric study of the muscular branches of the median nerve. J Anat. 1996 Oct; 189 (pt 2): 445-9.

101. ***Olson IA*** – The origin of the lateral cutaneous nerve of forearm and its anaesthesia for modified brachial plexus block. J Anat. 1969 Sep; 105 (2): 381-2.

102. ***Ongoiba N, Destrieux C, Koumatc AK***- Anatomical variations of the brachial plexus.

Morphologie.2002 June; 86(273):31-4.

103. ***Partridge BL, Katz J, Benirschke K*** – Functional anatomy of the brachial plexus sheath: implications for anaesthesia. Anaesthesiology. 1987 Jun; 66(6): 743-7.

104. ***Paterson AM*** – A discussion of some points of the distribution of the spinal nerve.J Anat Physiol. 1896; 30: 350-358.

105. ***Poynter WL*** – Congenital anomalies of the arteries and veins of the human body. Univ Nehr. 1920; 22:1-105.

106. ***Prasada Rao PV, Chaudhary SC –*** Communication of the musculocutaneous nerve with median nerve. East Afr Med J. 2000 Sep; 77(9): 498-503.

107. ***Presta M*** – The primary cords of the brachial plexus in the foetus and adult; Structural aspects and practical correlation with the anterior scalenus syndrome. Boll Soc Ital Biol Sper.1963 July 31; 39: 820-2.

108. ***Propeck T, Quinn TJ, Jacobson JA, Paulino AF, Habra G, Darian VB*** – Sonography and MR imaging of bifid median nerve with anatomic and histologic correlation. AJR Am J Roentgenol. 2000 Dec; 175(6): 1721-5.

109. ***Richardson GA, Humphery MS*** – Congenital compression of the radial nerve. J Hand Surg (Am). 1989 Sep; 14(5): 901-3.

110. ***Roberts WH*** – Anomalous course of median nerve medial to the trochlea and anterior to the medial epicondyle of humerus. Anat anz. 1992 Aug; 174(4): 309-11.

111. ***Saeed M, Rufai AA***- Medianand muaculocutaneous nerves: variant formation and distribution .Clin Anat. 2003 Sep; 16(5): 453-7.

112***. Sanes HD, Reh TA and Harris WA***- Development of the nervous system In: Axon growth and guidance. Academic Press, New York. Pp 189 - 197 (2000).

113***. Sargen MF, Uslu SS, Celik HH, Akoit D*** – A variation of the median nerve at the level of brachial plexus. Bull Assoc Anat (Nancy). 1995 Sep; 79 (246): 25-6.

114. ***Saundo JR, Chikwe J, Evans SE*** – Anomalous median nerve associated with persistent median artery. J Hand Surg (Am). 1994 Mar; 19 (2): 199-202.

115. ***Shu HS, Chantelot C*** – Martin – Gruber communicating branch: Anatomical and Histological study. Surg Radiol Anat. 1999; 21: 115-118.

116. ***Song WC, Jung HS, Kim HT, Shin C, Lee BY, K oh KS*** – A variation of the musculocutaneous nerve absent. Yonsei med J. 2003 Dec 30; 44(6): 1110 – 3.

117. ***Srivastava SK, Pande BS*** – Anomalous pattern of median artery in the forearms of Indians. Acta Anat (Basel). 1990; 138 (3): 193-4.

118***. Stancic MF, Micovic V, Potocnjak M***- The anatomy of the Berrettini branch: Implications for carpal tunnel release. J Neurosurg. 1999 Dec; 91(6): 1027-30.

119. ***Steinberg EL, Luger E, Taitz C, Arensburg B*** – Anatomic variant of the median nerve in the carpal tunnel. Chir Orthop Relat Res. 1998 Jul; 352: 128-30.

120***. Still JM Jr, Kleinert HE*** – Anomalous muscles and nerve entrapment in the wrist and hand. Plast Reconstr Surg. 1973 Oct; 52(4): 394-400.

121. ***Taams KO*** – Martin – Gruber connection in South Africa, an anatomical study. J Hand Surg (Br). 1997 Jun; 22(3):328-30.

122. ***Takami H, Takahashi S, Ando M*** – Bipartite median nerve with a double compartment within the transverse carpal canal. Arch Orthop Trauma Surg. 2001; 121(4): 230-1.

123. ***Tatar I, Brohi R, Sen F, Tonak A,Celik H*** – Innervation of the coracobrachialis by a branch from the lateral root of the median nerve. Folia morphol (Warsz). 2004 Nov; 63(4): 503-6.

124. ***Thane GD*** - Arthroscopy myology angiology In: Schafer EA, Thane GD – Quain's elements of anatomy. 10th Ed; Longmans, Green and Co. London. (1892); pp 223-224: 439-441.

125. ***Tillman B, Gretenkord K*** – The course of the median nerve in the carpal tunnel. Morphol med. 1981Feb; 1(1):61-9.

126. ***Trotter M, Henderson JL, Grass H*** – The origins of the branches of the axillary artery in Whites and American Negroes. Anat Roc. 1930; 46: 133-137.

127. ***Tsikaras PD, Agiabasis A, Hytiroglou PM*** – A variation in the formation of the brachial plexus characterized by the absence of C8 and T1 fibers in the trunk of median nerve. Bull Assoc.Anat (Nancy).1983 Dec; 67(199): 501-5.

128. ***Tubbs RS., Oakes WJ., Blount JP., Elton S., Salter G., Grabb PA*** – Surgical landmarks for the proximal portion of the axillary nerve. J Neurosurg. 2001 Dec: 95(6): 998-1000.

129. ***Turner W.M*** –On some variations in the arrangement of the nerves of the human body. Natural history review. 1864; 4: 612-17.

130. ***Urban T, Krosman M*** – Variation of the median nerve in the forearm and the wrist. Folia Morphol (Warsz). 1992; 51(1):77-9.

131. ***Urbanowicz Z*** – Various characteristics of the internal structure of the suprascapular nerve in man. Ann Univ Mariae Curie Sklodowska (mwd). 1982; 37: 259-65.

132. ***Urbanowicz Z*** – The lateral root of the median nerve and its fascicles in the human – Ann Univ Mariae Curie Sklodowska (Med). 1992; 47: 49-54.

133. ***Urbanowicz Z*** – Terminal divisions of the inferior trunk of the brachial plexus in man. Ann Univ Mariae Curie Sklodowska (med). 1994; 48: 67-74.

134. ***Uysal II, Sekar M, Kasabulut AK, BuyukmumluM, Ziylan T***-Brachial plexus variations in human fetuses. Neurosurgery.2003 Sept; 53(3);676-84.

135. ***Vallois HV*** – Recherches sur le trajet et les anastomosis du nerf musculocutane au nivcau du bras (etude statistigue). Archives Anatomy Histology Embryology. 1922; 1: 184-204.

136. ***Van Schroeder HP, Scheker LR*** – Redefining the " Arcade of Struthers". J Hand Surg(Am).2003 Nov; 28(6):1018-21.

137. ***Vasickova Z*** – Neural anastomosis in the human forearm. Folia morphol (Praha). 1977; 25(4): 396-9.

138***. Venieratos D, Anagnostopoulou S*** – Classification of communications between the musculocutaneous nerve and median nerves. Clin Anat. 1998; 11(5): 327-331.

139. ***Vyshnepol'skii Alu, Guzhov DA*** – Redkije varianty formirovanija nervov I arterij pleca celovela. Morfologia. 2001; 119:24-25.

140. ***Wadhwa S, Mehra S, Khan RQ, Kapur V*** – Abnormal musculoaponeurotic tunnel in the arm: Possible entrapment of the median nerve and brachial artery with high origin of nerve to pronator teres within the tunnel. Clin Anat. 2004 May; 17(4): 360-3.

141***. Walsh JF*** – The anatomy of the brachial plexus. Am J M Sci. 1877; 74: 387-428.

142.***Watanabe M, Takatsuji K, Sakamoto N, Morita Y, Ito H*** – Two cases of fusion of musculocutaneous nerve and median nerve. Kaibogaku Zasshi. 1985 Feb; 60(1):1-7.

143. ***Williams PL, Bannister LH, Berry MM, Collins P, Dyson M, Dussek JE and Ferguson MWJ*** – Gray's Anatomy In: Nervous system. 38th Edn. Churchill Livingston Edinburgh. 1995; pp 1266-1274.

144. ***Winkelman NZ*** – Aberrent sensory branch of the median nerve to the third web space- Case report. J Hand Surg (Am). 1980 Nov; 5(6): 566-7.

145. ***Yan J, Aizawa Y, Honma S, Horiguchion***- Re – evaluation of the human brachialis muscle by fiber analysis of supply nerves. Kaiboguka Zasshi. 1998 Jun; 73(3): 247-58.

146. ***Yan J, Wu H, Aizawa Y, Hinguchion*** – The human suprascapular nerve belongs to both anterior and posterior divisions of the brachial plexus. Okajimas Folia Anat Jpn.1999 Oct; 76(4): 149-55.

147. ***Yang ZX, Pho RW, Kour AK, Percira BP***- The musculocutaneous nerve and its branches to the biceps and brachialis muscles. J Hand Surg (Am). 1995 Jul; 20(4): 671-5.

148***. Zagrebin AM, Chuchkov VM*** – Formation of the neurovascular connection in human forearm muscles. Arkh Anat Gistol Embryol. 1980 Oct; 79(10): 67-73.

149. ***Zverina E, Stejskal L***- Poraneni peri fernich nervic. Praha; Avicenum; 1979: 303.